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Work Plan for a Treatability Study in Support of the Intrinsic Remediation (Natural Attenuation) Option at IRP Site - 16



**Langley Air Force Base
Hampton, Virginia**

Prepared For

**Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas**

and

**1 CES/CEVR
Langley Air Force Base
Hampton, Virginia**

June 1995



**PARSONS
ENGINEERING SCIENCE, INC.**

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**WORK PLAN FOR A TREATABILITY STUDY
IN SUPPORT OF THE INTRINSIC REMEDIATION
(NATURAL ATTENUATION) OPTION FOR
IRP SITE SS-16**

at

**LANGLEY AIR FORCE BASE
HAMPTON, VIRGINIA**

June 1995

Prepared for:

**AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS**

AND

**1 CES/CEVR
LANGLEY AIR FORCE BASE
HAMPTON, VIRGINIA**

Prepared by:

**Parsons Engineering Science, Inc.
57 Executive Park South, N.E., Suite 500
Atlanta, Georgia 30329-2265**

TABLE OF CONTENTS

	Page
SECTION 1 INTRODUCTION	1-1
1.1 SCOPE OF CURRENT WORK PLAN	1-2
1.2 BACKGROUND	1-3
SECTION 2 DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT	2-1
2.1 DATA REVIEW	2-1
2.1.1 Topography, Surface Hydrology, and Climate	2-1
2.1.2 Overview of Geology and Hydrogeology	2-3
2.1.2.1 Regional Geology and Hydrogeology	2-3
2.1.2.2 Site Geology and Hydrogeology at Building 771	2-4
2.1.3 Soil Quality	2-6
2.1.4 Groundwater Quality and Chemistry	2-6
2.2 DEVELOPMENT OF CONCEPTUAL MODEL	2-9
2.2.1 Intrinsic Remediation and the Bioplume II Model	2-9
2.2.2 Biodegradation of Dissolved BTEX Contamination	2-10
2.2.3 Initial Conceptual Model	2-11
2.2.4 Potential Pathways and Receptors	2-12
SECTION 3 COLLECTION OF ADDITIONAL DATA	3-1
3.1 SOIL SAMPLING	3-2
3.1.1 Sample Collection Using the Geoprobe® System	3-2
3.1.2 Soil Sampling Locations and Required Analyses	3-5
3.1.3 Datum Survey	3-8
3.1.4 Site Restoration	3-8
3.1.5 Equipment Decontamination Procedures	3-9
3.2 GROUNDWATER SAMPLING	3-10
3.2.1 Monitoring Point Locations and Completion Intervals	3-10
3.2.2 Monitoring Point Installation Procedures	3-10
3.2.2.1 Pre-Placement Activities	3-10
3.2.2.2 Monitoring Point Materials Decontamination	3-11
3.2.2.3 Installation and Materials	3-11
3.2.2.3.1 Deep Monitoring Points	3-11
3.2.2.3.2 Shallow Monitoring Points	3-12
3.2.2.4 Monitoring Point Completion	3-14
3.2.2.5 Monitoring Point Abandonment and Site Restoration	3-14
3.2.2.6 Monitoring Point Development and Records	3-14
3.2.3 Groundwater Grab Sampling Procedures	3-15
3.2.4 Monitoring Point Location and Datum Survey	3-17
3.2.5 Water Level Measurements	3-17
3.2.5.1 Manual Water Level Measurements	3-17
3.2.5.2 Automatic Water Level	3-18
3.2.5.2.1 Equipment	3-18
3.2.5.2.2 Data Collection Procedures	3-18

3.3	GROUNDWATER SAMPLING	3-20
3.3.1	Preparation for Sampling	3-21
3.3.1.1	Equipment Cleaning	3-21
3.3.1.2	Equipment Calibration.....	3-24
3.3.2	Sampling Procedures	3-24
3.3.2.1	Preparation of Location	3-24
3.3.2.2	Water Level and Total Depth Measurements	3-25
3.3.2.3	Monitoring Well/Point Purging	3-25
3.3.2.4	Sample Extraction	3-26
3.3.3	Onsite Groundwater Parameter Measurement.....	3-26
3.3.3.1	Dissolved Oxygen Measurements.....	3-26
3.3.3.2	pH, Temperature, and Specific Conductance	3-27
3.3.3.3	Alkalinity Measurements	3-27
3.3.3.4	Nitrate- and Nitrite-Nitrogen Measurements.....	3-27
3.3.3.5	Carbon Dioxide Measurements	3-28
3.3.3.6	Sulfate and Sulfide Sulfur Measurements.....	3-28
3.3.3.7	Total Iron, Ferrous Iron, and Ferric Iron Measurements	3-28
3.3.3.8	Manganese Measurements	3-28
3.3.3.9	Redox Potential	3-28
3.4	SAMPLE HANDLING FOR LABORATORY ANALYSIS	3-29
3.4.1	Sample Preservation.....	3-29
3.4.2	Sample Containers and Labels	3-29
3.4.3	Sample Shipment.....	3-30
3.4.4	Chain-of-Custody Control.....	3-30
3.4.5	Sampling Records.....	3-31
3.4.6	Laboratory Analyses.....	3-32
3.5	AQUIFER TESTING	3-32
3.5.1	Definitions.....	3-33
3.5.2	Equipment.....	3-33
3.5.3	General Test Methods.....	3-34
3.5.4	Falling Head Test	3-34
3.5.5	Rising Head Test	3-37
3.5.6	Slug Test Data Analysis	3-37
SECTION 4 REMEDIAL OPTION EVALUATION AND TS REPORT.....		4-1
SECTION 5 QUALITY ASSURANCE/QUALITY CONTROL		5-1
SECTION 6 REFERENCES		6-1
APPENDIX A CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING REQUIREMENTS FOR GROUNDWATER SAMPLES		
APPENDIX B AVAILABLE SOIL AND GROUNDWATER ANALYTICAL RESULTS AND SOIL BORING LOGS		

LIST OF TABLES

	Page
2.1 Hydrogeologic Units Underlying Langley AFB	2-5
2.2 Summary of Phase I Soil Sample Results	2-7
3.1 Analytical Protocol for Groundwater and Soil.....	3-3
4.1 Example TS Report Outline.....	4-2
5.1 QA/QC Sampling Program	5-2

LIST OF FIGURES

	Page
1.1 Base Location Map.....	1-4
1.2 Base Map With Site Location	1-6
1.3 IRP Site SS-16 Vicinity Map	1-7
1.4 Potential Sources of Fuel Contamination.....	1-8
2.1 Geologic Map of Virginia	2-2
2.2 Preliminary Groundwater and Soil Analytical Results (late 1994)	2-8
3.1 Cross Section of Geoprobe®	3-4
3.2 Geologic Boring Log.....	3-6
3.3 Proposed Geoprobe® Sampling and/or Monitoring Point Installation Locations.....	3-7
3.4 Monitoring Point Installation Record	3-13
3.5 Monitoring Point Development Record.....	3-16
3.6 Groundwater Sampling Record.....	3-22
3.7 Aquifer Test Data Form.....	3-35

SECTION 1

INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES) [formerly Engineering-Science, Inc. (ES)], presents the scope of work required for the collection of data necessary to conduct a treatability study (TS) for remediation of groundwater contaminated with petroleum hydrocarbons at Installation Restoration Program (IRP) Site SS-16 (a former military gasoline service station site), Langley Air Force Base (AFB) in Hampton, Virginia. Hydrogeologic and groundwater chemical data necessary to evaluate multiple remedial options will be collected under this program; however, this work plan is primarily oriented toward the collection of hydrogeologic data to be used in support of intrinsic remediation (natural attenuation) for restoration of fuel-hydrocarbon-contaminated groundwater. Other remedial options will be considered in conjunction with intrinsic remediation during the TS, including free product removal; groundwater extraction and treatment (i.e., pump and treat); biosparging; bioslurping; and long-term monitoring.

Data collected during the TS also will be used as input into the Bioplume II groundwater solute transport model code. As part of the TS, the Bioplume II modeling effort has three primary objectives: 1) to predict the future extent and concentration of the dissolved-phase contaminant plume by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) to assess the possible risk to potential downgradient receptors; and 3) to provide technical support for selection of the intrinsic remediation option as the best remedial alternative at regulatory negotiations, as appropriate. The TS and the Bioplume II modeling effort for IRP Site SS-16 will involve completion of several tasks, which are described in the following sections.

This work plan was developed based on discussions among representatives from the Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division, Langley AFB, and Parsons ES at a meeting at the Base on March 16, 1995; on the statement of work (SOW) for this project; and on a review of existing site characterization data. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative*

(ES, 1993) and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and Langley AFB.

1.1 SCOPE OF CURRENT WORK PLAN

The ultimate objective of the work described herein is to provide a TS for remediation of groundwater contamination at IRP Site SS-16. However, this project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with the US Environmental Protection Agency (EPA) and Parsons ES to document the biodegradation and resulting attenuation of fuel hydrocarbons and solvents dissolved in groundwater, and to model this degradation using the Bioplume II numerical groundwater model. For this reason, the work described in this work plan is directed toward the collection of data in support of this initiative. All data required to develop a 30-percent design of an alternate remediation system, should intrinsic remediation not prove to be a viable remedial option at this facility, also will be collected under this program. This work plan describes the site characterization activities to be performed in support of the TS and the Bioplume II modeling effort. Field activities will be performed to determine the extent of residual, free-phase, and dissolved contamination at IRP Site SS-16. These data will be used along with data from previous investigations to complete the characterization of contaminants at the site and for use in the Bioplume II model to predict the future concentrations and extent of contamination.

Site characterization activities in support of the TS will include: 1) determination of preferential contaminant migration pathways; 2) soil and groundwater sampling using the Geoprobe[®] apparatus; 3) groundwater monitoring point placement; and 4) aquifer testing. The materials and methodologies required for performance of these activities are described herein. Existing site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the Bioplume II model. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site, to be obtained from widely accepted published literature, will be used for model input. Sensitivity analyses will be conducted for the parameters that are known to have the greatest influence on the results of Bioplume II modeling, and where possible, the model will be calibrated using historical site data. Upon completion of the Bioplume II modeling, Parsons ES will provide technical assistance at regulatory negotiations to support the intrinsic remediation option if the results of the modeling indicate that this approach is warranted. If it is shown that intrinsic remediation is not the most appropriate remedial option, Parsons ES will

recommend the most appropriate groundwater remedial technology based on available data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of existing site-specific data and a conceptual model for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and TS report format. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. There are two appendices to this work plan. Appendix A contains a listing of containers, preservatives, packaging, and shipping requirements for groundwater samples. Appendix B contains a summary of existing soil and groundwater analytical data from previous field investigation work..

1.2 BACKGROUND

Langley AFB is located in Hampton City in southeastern Virginia. The Base covers approximately 2,900 acres and is located within the outer coastal plain physiographic province of Virginia (Figure 1.1). The Base is bordered by the city of Hampton on the south, the city of Poquoson on the north, and is approximately 1 mile east of the city of Newport News. Norfolk is approximately 12 miles south-southeast of the Base. The Back River forms the northeastern and southeastern borders of the Base and discharges into Chesapeake Bay, approximately 3 miles east of the Base. Predominant land uses outside of Langley AFB are residential, light industrial, and commercial.

Langley Field, the predecessor of Langley AFB, became operational in 1917. The mission of Langley Field has varied throughout its time of operation. Langley Field officially became Langley AFB in January of 1948, shortly after the formation of the US Air Force (USAF) Tactical Air Command (TAC) at the Field. Langley AFB became the headquarters for the USAF Air Combat Command (ACC) in June 1992, after the TAC was inactivated as part of USAF restructuring (USAF, 1993). The 1st Fighter Wing under the ACC is the host unit of Langley AFB. The primary mission of the Wing is to maintain rapid combat capability for rapid global deployment to conduct air superiority operations (USAF, 1994). Approximately 9,000 permanent military personnel are assigned to Langley AFB, and about 3,000 civilians are employed at the Base (USAF, 1993).

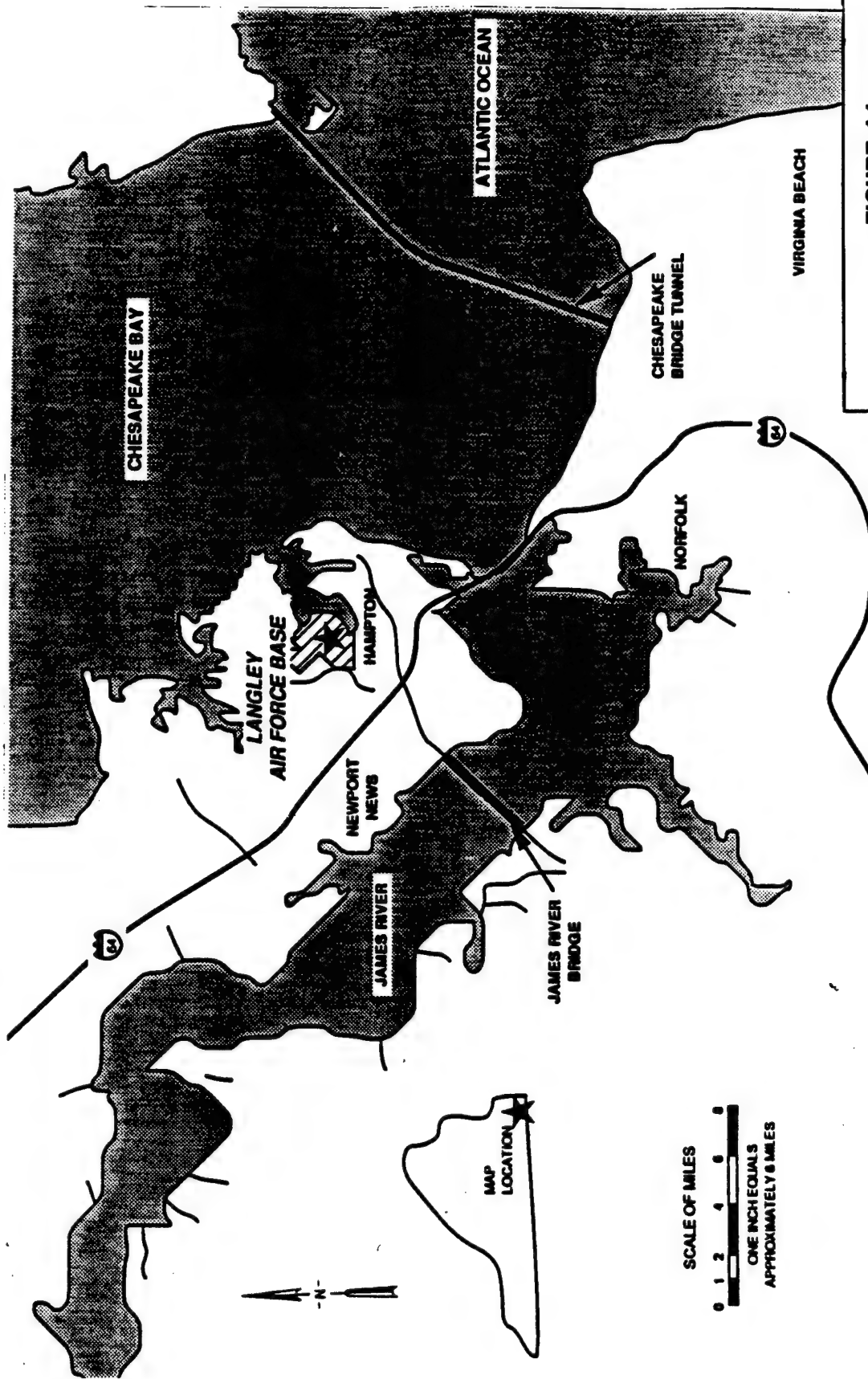


FIGURE 1.1

BASE LOCATION MAP

IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA



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IRP Site SS-16 (the Site) is located in the southeastern portion of the Base between Building 590 and 596 in an asphalt paved parking lot (Figures 1.2 and 1.3). The following site history information was reported in a work plan prepared by Radian Corporation and Law Environmental in January 1993 (Radian and Law, 1993). The site was identified as area of suspected fuel contamination during an IRP record search conducted by CH2MHill in 1981. The suspected sources of contamination at the site include several former underground storage tanks (USTs) used to store fuel oil as part of a service station. These USTs were 550 gallons in size and were reportedly removed (date unknown). Analysis of historic aerial photographs taken in the 1930s and 1940s indicated that a structure which was possibly a gas station, was located near the present location of Buildings 590 and 596. A photograph from 1932 also showed that four aboveground storage tanks (ASTs) (contents unknown) and a possible drum storage area were located in the area (Figure 1.4). These ASTs were reportedly removed by 1937. A railroad track running through the area was also identified in the photograph and was reportedly removed by 1937. As reported by Radian, an architectural survey indicated that Building 596 was a gas station and oil house when it was first constructed in the 1930s. More recently in 1991, black fuel product was discovered at depths of up to 3 feet below ground surface during excavation activities performed between Buildings 590 and 596 (Radian and Law, 1993).

Work has been performed at the site by Water and Air Research, Inc. (WAR, 1982) and by Radian and Law (1993) to attempt to define the extent of fuel contamination.

A Phase I record search, conducted by CH2MHill in 1981, identified 12 areas of potential contamination. IRP Site SS-16, referred to as Area 16, was recognized as an area of suspected fuel contamination. In response to the Phase I investigation, a Phase II - Field Confirmation Study was conducted by WAR in 1982 to determine the presence or absence of contamination in these 12 areas. At Area 16, soil samples collected from two shallow corings indicated fuel contamination was present in the soil. However, based on the available site history, these samples may have been collected from an area away from the site (see Figure 1.4).

In 1994, an site investigation was conducted by Radian and Law (1995) to determine the presence or absence of contamination in soil and groundwater at the site. Six borings were installed to groundwater. Three of the six borings were completed

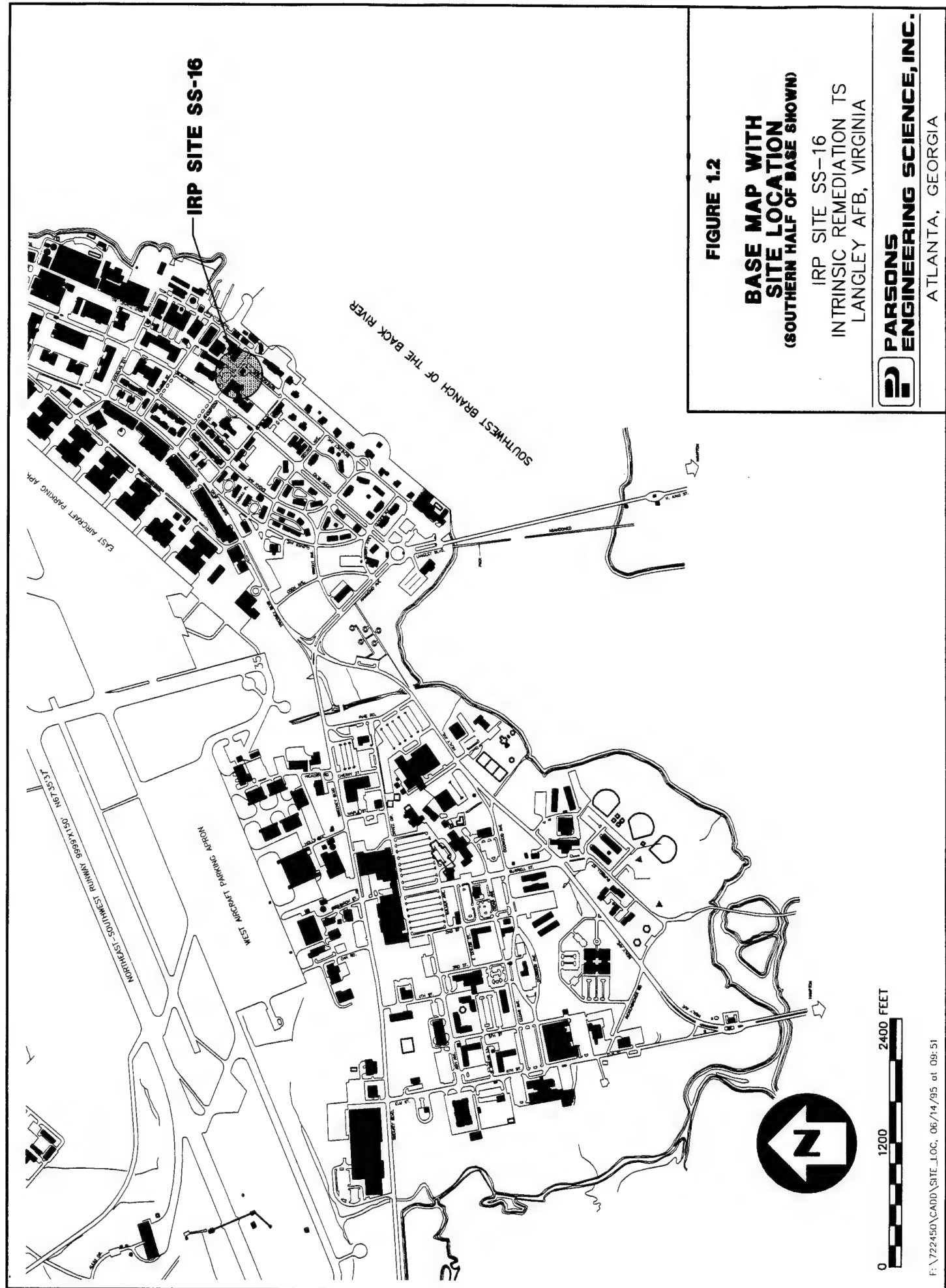


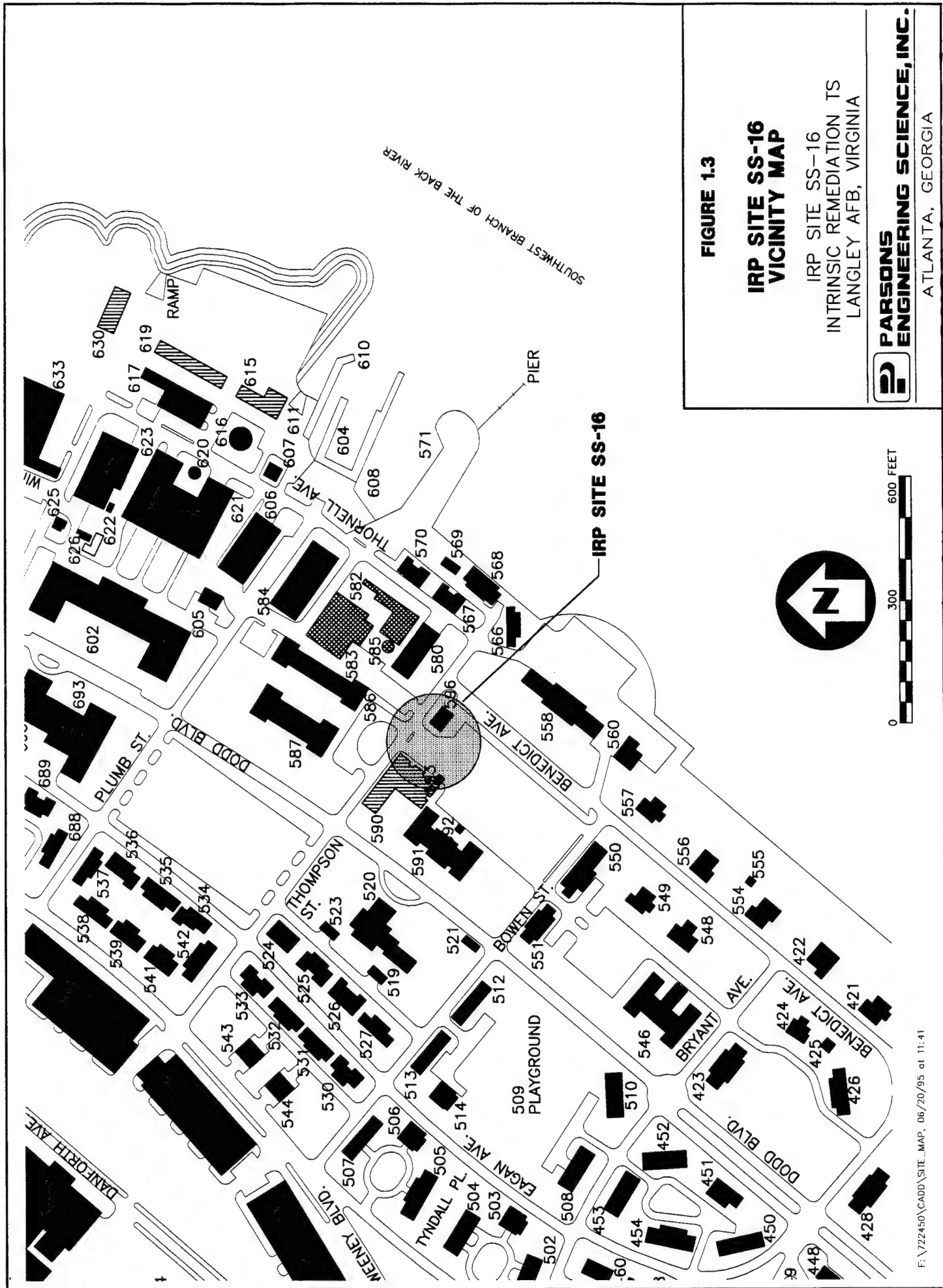
FIGURE 1.2

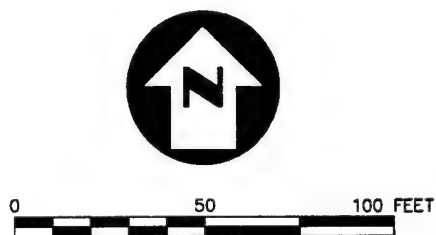
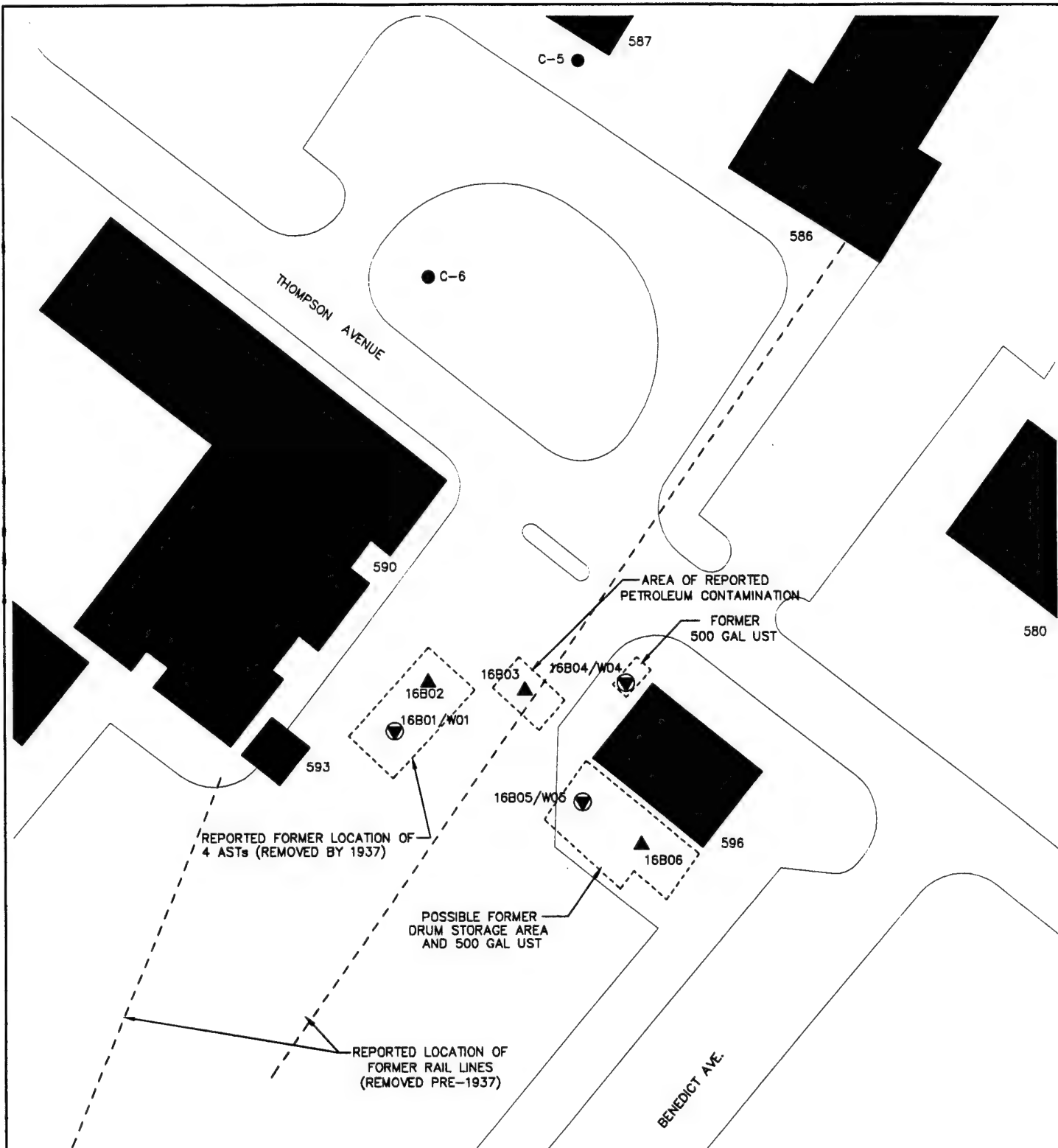
**BASE MAP WITH
SITE LOCATION
(SOUTHERN HALF OF BASE SHOWN)**

IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA



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ATLANTA, GEORGIA





LEGEND

- SOIL SAMPLING LOCATIONS USED BY W.A.R. IN 1982
- ▲ SOIL BORINGS (LATE 1994)
- EXISTING WELL LOCATION

FIGURE 1.4 POTENTIAL SOURCES OF FUEL CONTAMINATION

IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA



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as monitoring wells (Figure 1.4). At the time of this writing, the investigation results report was being prepared and few results were available. The available information indicated that at a minimum, arsenic was detected in soil, and benzene was detected in the shallow groundwater at the site.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Site-specific data were reviewed and used to develop a conceptual model for groundwater flow and contaminant transport at IRP Site SS-16. This conceptual model guided the selection of sampling locations and the identification of analytical data requirements to support the Bioplume II modeling effort and to evaluate potential remediation technologies, including intrinsic remediation. Section 2.1 presents a synopsis of available site data. Section 2.2 presents the preliminary conceptual groundwater flow and contaminant transport model that was developed based on these data.

2.1 DATA REVIEW

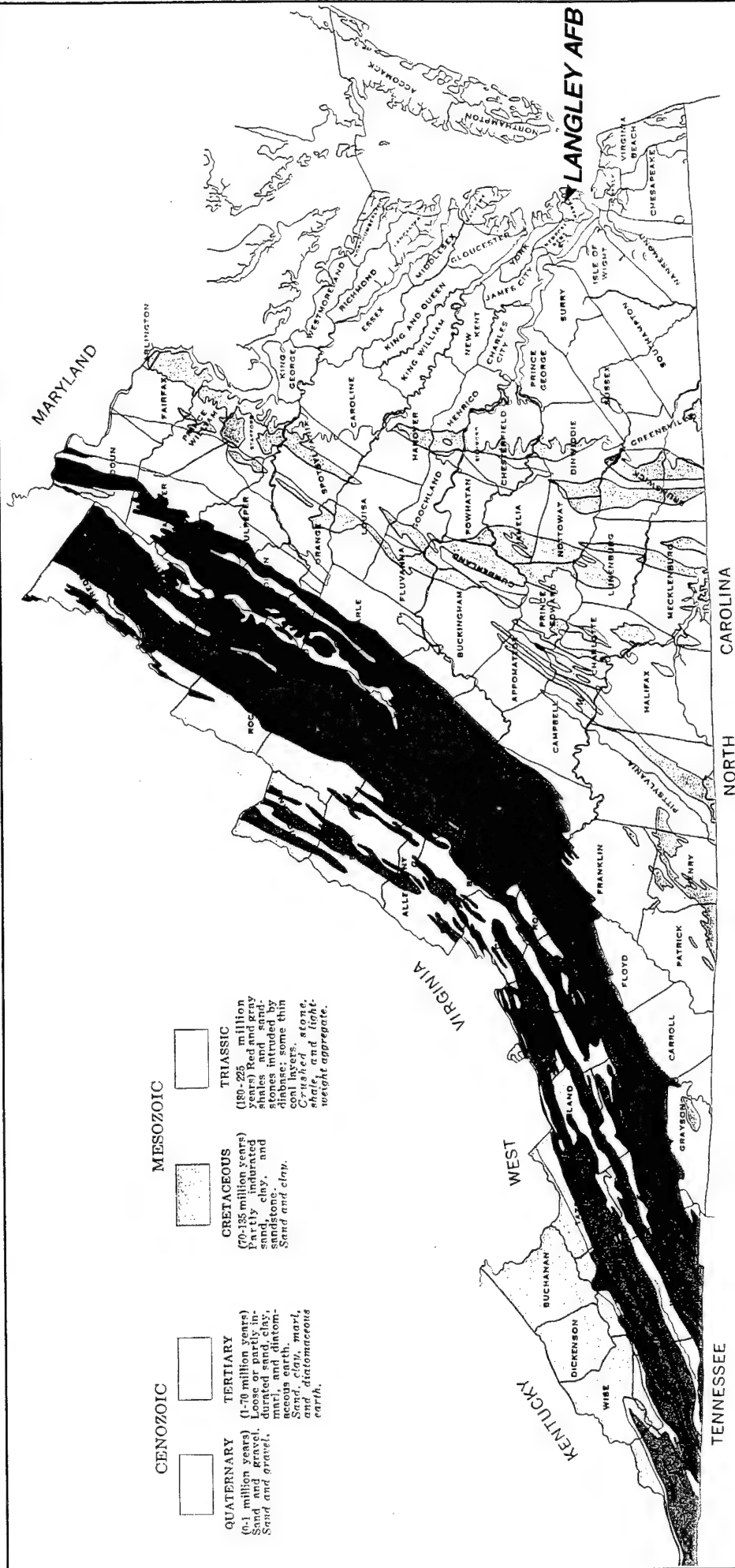
The following sections are based upon review of data from the following sources:

- Phase II - Field Evaluation Report for Langley AFB (WAR, 1982), and
- Work Plan, Volume I, Draft Work Plans, CAP/ESI/SI Planning Documents (Radian and Law, 1993)

2.1.1 Topography, Surface Hydrology, and Climate

Langley AFB is located in the coastal plain of southeastern Virginia (Figure 2.1) on the York-James Peninsula, which is bounded by the York River on northeast, Chesapeake Bay on the east, and the James River on the south and southwest. The area is characterized by a low, relatively flat terrain with little relief. Land surface elevations in the vicinity of Langley AFB range from 0 to 20 feet above mean sea level (msl). There are minor variations in elevation at the Base ranging from 0 to 12 feet msl.

The Back River is the surface water body closest to the Base, forming the southeast and northeast Base boundaries. The Base is located on a wide peninsula where the Southwest Branch and the Northwest Branch of the Back River join to form the Back River. Both Branches of the Back River originate in nearby Newport News City (to the west). From Langley AFB, the Back River flows 3 miles eastward and discharges into Chesapeake Bay. Both the Southwest Branch and Northwest Branch of the Back River



- CENOZOIC**
- QUATERNARY** (0-1 million years)
Sand and gravel.
Sand and gravel.
 - TERTIARY** (1-70 million years)
Loose or partly indurated sandstone, clay, and siltstone.
Sand, clay, marl, and diatomaceous earth.
- MESOZOIC**
- CRETACEOUS** (70-135 million years)
Partly indurated sandstone, clay, and siltstone.
Sand and clay.
 - TRIASSIC** (180-225 million years)
Shales and sandstones intruded by diabase; some thin coal layers.
Crystalline slate, light and light weight aggregate.

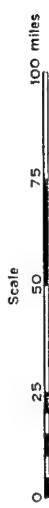
- PALEOZOIC**
- PENNSYLVANIAN** (270-310 million years)
Sandstone, shale, and coal.
Sand, coal, shale, and natural gas.
 - MISSISSIPPIAN** (310-400 million years)
Sandstone, shale, and coal.
Sand, coal, shale, and natural gas.
 - DEVONIAN** (400-500 million years)
Limestone, shale, and sandstone.
Sandstone, shale, and sand.
 - SILURIAN-ORDOVICIAN** (400-500 million years)
Limestone, shale, and sandstone.
Sandstone, shale, and sand.
 - CAMBRIAN** (500-600 million years)
Dolomite, shale, and sandstone.
Sandstone, shale, and sand.
 - VIRGINIA BLUE RIDGE COMPLEX** (Older than 600 million years)
Granite, gneiss, and schist.
Crushed stone.
- ROCKS OF UNCERTAIN AGE**
- GRANITE and GNEISS**
Granite, gneiss, and schist.
Crushed stone.
 - METAMORPHIC ROCKS and IGNEOUS INTRUSIVES**
Schist, slate, phyllite, and marble.
Metamorphosed arkose and conglomerate; greenstone, diorite, and gabbro.
Crushed stone, soapstone, orthogneiss, slate, dimension stone, kyanite, feldspar, apatite, and titanium minerals.

FIGURE 2.1

GEOLOGIC MAP OF VIRGINIA

IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA

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Source: Commonwealth of Virginia, Department of Mines, Minerals and Energy
Division of Mineral Resources, 1987

experience tidal fluctuations. Normal tidal fluctuations in the Hampton area are about 2.5 feet in magnitude (Johnson, 1976). Important tributaries to the Back River include Tabbs Creek, Tide Mill Creek, Harris River, Newmarket Creek, and Brick Kiln Creek. Surface water drainage from Langley AFB flows into Tabbs Creek, Tide Mill Creek, Southwest Branch of the Back River, and Northwest Branch of the Back River by direct runoff, runoff into artificial and natural drainage features that eventually discharge to these water bodies, and through the Base stormwater discharge system. A primary branch of Tide Mill Creek originates in the south-central portion of the Base and flows south along the Base boundary before discharging into Tide Mill Creek. Tide Mill Creek flows a short distance along the southern boundary of the Base before discharging into Southwest Branch of the Back River. Tabbs Creek originates in the northwest portion of the Base and flows northeast before discharging into Northwest Branch of the Back River. Several small tributaries of Brick Kiln Creek originate in the northwest corner of the Base and eventually flow into the Northwest Branch of the Back River. Surface water and stormwater from the vicinity of IRP Site 16 is reported to flow toward Southwest Branch of the Back River, which is approximately 350 feet to the southeast.

Langley AFB experiences a marine climate characterized by warm, humid, moderately wet summers and mild winters. Average daily winter temperatures from December through February are 42 degrees Fahrenheit (°F). Spring, summer, and fall mean daily temperatures range from 40°F to 86°F. The mean annual precipitation is 44.5 inches, and the mean annual snowfall is 9 inches.

2.1.2 Overview of Geology and Hydrogeology

2.1.2.1 Regional Geology and Hydrogeology

Langley AFB is located on the far eastern end of the York-James Peninsula in southeastern Virginia. Known as the Outer Coastal Plain, this area is characterized by a series of plains, created under subaqueous conditions, and scarps, former shorelines of Chesapeake Bay or the James River during the Pleistocene Epoch (Johnson, 1976). Langley AFB lies on the Hampton Flat, which is the principal physiographic feature of lower York County. The Peninsula is bounded on the southwest by the James River and on the east by Chesapeake Bay. Exposed sediments of this area are of Pliocene, Pleistocene, and Holocene (recent) age. Alluvium, marsh sediment, and beach and dune sand also are present. Surficial soils at Langley AFB consist almost entirely of the Lynnhaven Member of the Tabb Formation, which is described as beach and nearshore

marine sand and clay (Johnson, 1976). The Lynnhaven Member ranges in thickness from less than 0.5 foot to 8 feet in the area.

The Coastal Plain of Virginia is characterized by alternating sand and clay deposits that form a series of aquifers and confining units. A surficial aquifer, seven confined aquifers, and intervening confining units are formed by these deposits (Laczniak and Meng, 1988). A list of hydrogeologic units underlying Langley AFB, along with the estimated elevation of the top of each unit and the estimated thickness of each unit, is presented in Table 2.1. The ground surface elevation of the Base ranges from zero feet to approximately twelve feet above mean sea level.

The surficial aquifer at Langley AFB, the Columbia Aquifer, includes Holocene and Pleistocene age sediments and is approximately 60 feet thick. Sediments of this aquifer include interbedded and intermixed sand, silt, and clay, overlying a gravelly base (Laczniak and Meng, 1988). Groundwater occurs approximately 5 feet below ground surface (bgs) (Law, 1991).

Underlying the Columbia Aquifer is the Yorktown Confining Unit which is approximately 30 feet thick at Langley AFB. This unit is comprised mainly of silt and clay.

Located below the Yorktown Confining Unit is the Yorktown-Eastover Aquifer. This aquifer consists of sediments that are Pliocene and early Miocene in age and is approximately 155 feet thick at the Base. The main component of this aquifer is sand interbedded with silt, clay, shell beds, and gravel. Deposition of these sediments was the result of marine transgression (Laczniak and Meng, 1988).

2.1.2.2 Site Geology and Hydrogeology at IRP Site SS-16

Limited information is available on the geology and hydrogeology of IRP Site SS-16. However, based on investigations at nearby IRP Site 4, it is assumed that the geology and hydrogeology of SS-16 is consistent with the overall characteristics of Langley AFB. Thus, groundwater is anticipated to occur between 4 and 6 feet bgs and to flow southeastward to the Southwest Branch of the Back River, which eventually empties into Chesapeake Bay. Surficial soils consist of the Lynnhaven Member of the Tabb Formation, which is composed of interbedded sands and silts and possibly some gravel and shell fragments.

**TABLE 2.1 HYDROGEOLOGIC UNITS UNDERLYING LANGLEY AFB
IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA**

Formation	Estimated Elevation of Top of Unit (ft msl)	Estimated Thickness of Unit (ft)
Columbia Aquifer	+20	60
Yorktown Confining Unit	-40	30
Yorktown-Eastover Aquifer	-70	155
St. Marys Confining Unit	-225	75
Calvert Confining Unit	-300	140
Chickahominy-Piney Point Aquifer	-440	160
Nanjemoy-Marlboro Confining Unit	-600	50
Upper Potomac Confining Unit	-650	70
Upper Potomac Aquifer	-720	120
Middle Potomac Confining Unit	-840	30
Middle Potomac Aquifer	-870	430
Lower Potomac Confining Unit	-1300	60
Lower Potomac Aquifer	-1360	1140
Bedrock	-2500	--

Source: Lacznia and Meng, 1988.

2.1.3 Soil Quality

Available documents do not indicate historical leakage from the former fuel storage system at the site. In response to the Phase I record search in which Site SS-16 (known as Area 16) was identified as a potential source of fuel contamination, a Phase II Field Confirmation Study was conducted by WAR in 1982. Two soil borings were installed to a depth of 6 feet bgs, and soil samples were collected from 2, 4, and 6 feet bgs in each boring. These samples were analyzed for volatile and less volatile hydrocarbons by gas chromatograph and freon extraction, respectively. Fuel constituents were detected in these samples at concentrations up to 400 milligrams per kilogram (mg/kg) as shown in Table 2.2. However, WAR (1982) concluded that much of the organics detected were of non-fuel origin and may have been naturally occurring substances. WAR recommended no further study at the site. However, based on the available site history (Radian and Law, 1993), the WAR soil corings were not installed within the suspected area of fuel contamination, but rather were located north of the site across Thompson Avenue (Figure 1.4).

As part of the site investigation conducted by Radian and Law in 1994, six soil borings were installed at the site to determine if fuel constituents were present in shallow soils at the site. At the time of this writing, the report detailing results of this investigation was being prepared, and only limited, preliminary results were available. Arsenic was detected in boring 16B02, located in the reported former location of the four ASTs, at a concentration of 120 mg/kg (Figure 2.2). Parsons ES suspects that these preliminary results were limited to those detections that exceeded "trigger" levels, and that detections of arsenic and other compounds at concentrations below than the established "trigger" levels also may have been detected.

2.1.4 Groundwater Quality and Chemistry

Limited analytical data were available on the groundwater quality at Site SS-16. As part of the site investigation conducted by Radian and Law in 1994, three monitoring wells were installed at the site. The groundwater in these wells was reportedly sampled in late 1994 (Bartels, 1995). Based on preliminary information, benzene was detected in groundwater samples from two of the wells (W04 and W05) located near Building 596 at concentrations of 45.7 and 49.2 micrograms per liter ($\mu\text{g/L}$) (Figure 2.2). Arsenic also was detected in well W05 at a concentration of 0.08 $\mu\text{g/L}$ (Radian and Law, 1995). Parsons ES suspects that these preliminary results were limited to those detections that

TABLE 2.2
SUMMARY OF PHASE I SOIL SAMPLE RESULTS
IRP SITE 16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA

Sample Location	Depth (feet)	Volatile Hydrocarbons (mg/kg)	Hydrocarbons by Freon Extraction (mg/kg)	
C5	2	<1	a)	<30
			b)	N/A
C5	4	<1	a)	<30*
			b)	N/A
C5	6	<1	a)	<30*
			b)	N/A
C6	2	10	a)	350*
			b)	120
C6	4	<1	a)	400
			b)	230
C6	6	<1	a)	<30
			b)	N/A

Analytical Methods

Volatile Hydrocarbons - Sample purged with nitrogen at 80°C into a gas chromatograph (GC). Response compared with known amounts of aviation gasoline, diesel fuel and kerosene.

Hydrocarbons by Freon Extraction - Gravimetric procedure using freon extraction, which should detect less volatile, higher molecular weight compounds. Some volatile materials will be lost during the freon extraction step. Silica gel cleanup is intended to distinguish fuels from other natural organics in soils, by adsorbing fatty-acid type materials.

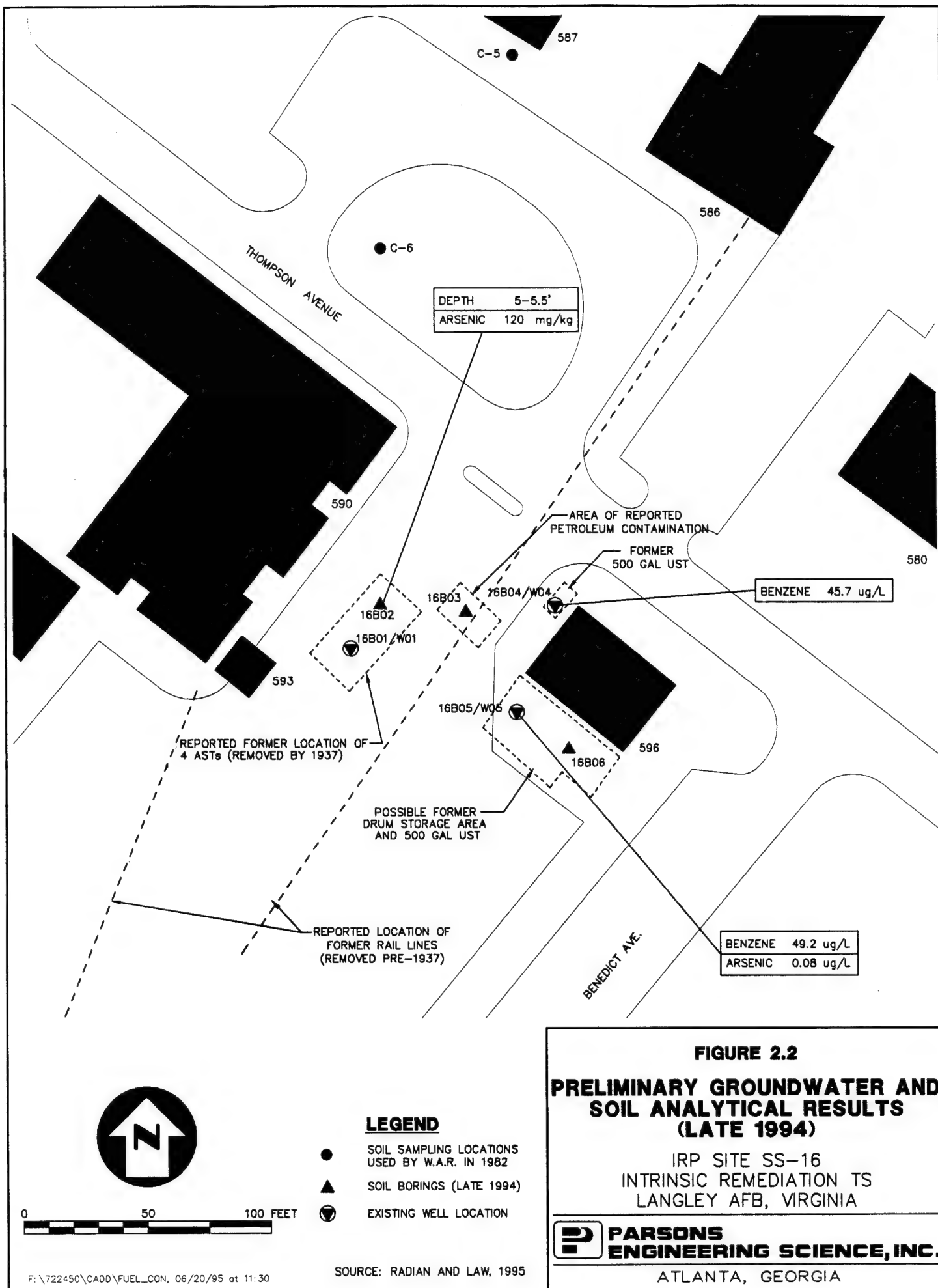
N/A = Not Analyzed

* = Sample previously purged

a) = No cleanup

b) = Silica Gel Cleanup

Source: Radian and Law, 1995



exceeded "trigger" levels, and that detections of benzene, arsenic, and other compounds at concentrations less than the established "trigger" levels also may have been detected.

2.2 DEVELOPMENT OF CONCEPTUAL MODEL

A conceptual model is a three-dimensional representation of the hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. The purpose of developing a site conceptual model is to provide an understanding of contaminant fate and transport mechanisms and to identify additional data requirements. The model describes known and suspected sources of contamination, types of contamination, affected media, and contaminant migration pathways. The model provides a foundation for formulating decisions regarding additional data collection activities and potential remedial actions. The conceptual model for IRP Site SS-16 will be used to aid in selecting additional data collection points and to identify appropriate data needs for modeling hydrocarbon degradation using the Bioplume II model.

Successful conceptual model development involves:

- Defining the problem to be solved;
- Integrating available data, including
 - Local geologic and topographic data,
 - Hydraulic data,
 - Site stratigraphic data,
 - Contaminant concentration and distribution data;
- Evaluating contaminant fate and transport characteristics;
- Identifying contaminant migration pathways;
- Identifying potential receptors; and
- Determining additional data requirements.

2.2.1 Intrinsic Remediation and the Bioplume II Model

After a site has been adequately characterized, fate and transport analyses can be performed to determine the potential for contaminant migration and whether any exposure pathway for human or ecological receptors is complete. The Bioplume II model has proved useful for predicting BTEX plume migration and contaminant attenuation by natural biodegradation. The Bioplume II model (Rifai *et al.*, 1988) can be used to evaluate critical groundwater fate and transport processes that may be involved in some of the migration pathways to human and ecological receptors. Quantitative fate and

transport analyses can be used to determine what level and extent of remediation is required.

An important consideration in determining whether fuel hydrocarbon contamination presents a substantial threat to human health and the environment, and what type of remedial alternative will be most cost effective in eliminating or abating these threats, is an accurate estimate of the potential for natural biodegradation of benzene, toluene, ethylbenzene, and xylene (BTEX) compounds in the groundwater. Over the past two decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons (Lee, 1988). This process occurs naturally when sufficient oxygen (or other electron acceptors) and nutrients are available in the groundwater. The rate of natural biodegradation is generally limited by the lack of electron acceptors rather than by the lack of nutrients such as nitrogen or phosphorus.

2.2.2 Biodegradation of Dissolved BTEX Contamination

The Bioplume II model is a well-documented and widely accepted numerical model available for modeling the fate and transport of fuel hydrocarbons under the influence of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation. The positive effect of these processes on reducing the actual mass of fuel-related contamination dissolved in groundwater has been termed intrinsic remediation. The advantages of intrinsic remediation include: (1) contaminants are transformed to innocuous byproducts (e.g., carbon dioxide and water), not just transferred to another phase or location within the environment; (2) current pump-and-treat technologies are energy-intensive and generally not as effective in reducing residual contamination; (3) the process is nonintrusive and allows continuing use of infrastructure during remediation; (4) current engineered remedial technologies may pose a greater risk to potential receptors than intrinsic remediation because contaminants may be transferred into the atmosphere during remediation activities; and (5) intrinsic remediation is far less costly than conventional, engineered remedial technologies.

To estimate the impact of natural attenuation on the fate and transport of BTEX compounds dissolved in groundwater at a site, two important lines of evidence must be demonstrated (Wiedemeier *et al.*, 1995). The first is a documented loss of contaminant mass at the field scale. Dissolved concentrations of biologically-recalcitrant tracers found in most fuel contamination are used in conjunction with aquifer hydrogeologic parameters, such as groundwater seepage velocity and dilution, to demonstrate that a reduction in the

total contaminant mass is occurring at the site. The second line of evidence involves the use of chemical analytical data in mass balance calculations to show that areas with BTEX contamination can be correlated to areas with depleted electron acceptor (e.g., oxygen, nitrate, and sulfate) concentrations and increases in metabolic fuel degradation byproduct concentrations (e.g., methane and ferrous iron). With this site-specific information, the Bioplume II computer model can be used to simulate the fate and transport of dissolved BTEX compounds under the influence of the process of natural attenuation.

The Bioplume II model is based upon the US Geological Survey (USGS) two-dimensional (2-D) solute transport model (Konikow and Bredehoeft, 1978), which has been modified to include a biodegradation component that is activated by a superimposed plume of dissolved oxygen. Bioplume II solves the USGS 2-D solute equation twice, once for hydrocarbon concentrations in the groundwater and once for a dissolved oxygen plume. The two plumes are then combined using superposition at every particle move to simulate biological reactions between fuel products and oxygen. If appropriate, biodegradation of contaminants by anaerobic processes is simulated using a first-order anaerobic decay rate.

2.2.3 Initial Conceptual Model

No site specific geologic and hydrogeologic information was available for the site; however, data from nearby IRP Site 4 and literature references have provided sufficient information to develop an initial conceptual model. The depth to groundwater at the site is estimated to range from 5 to 8 feet bgs in the silty sand and clay deposits in the vicinity of the site. The general flow direction of groundwater is estimated to be to the southeast. Hydraulic gradients in other portions of the Base have reported as nondiscernible (Law, 1991), which is a possible result of a low overall gradient in the surficial aquifer and reported fluctuating water tables caused by tidal effects in the Back River. Vertical gradients are expected to be minor in the upper portion of the surficial aquifer beneath the site. Considering the underlying Yorktown confining unit, possible groundwater migration to deeper aquifers should be minimal. Based on available data, Parsons ES will model the site as an unconfined, silty sand aquifer. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

Based on the available site information, evidence of residual light nonaqueous-phase liquid (LNAPL), described as black fuel product, has been observed in the shallow soils at IRP Site 16 (Radian and Law, 1993). If LNAPL is encountered during subsurface

investigation, the fuel/water partitioning models of Bruce *et al.* (1991) or Cline *et al.* (1991) will be used to provide a conservative source term to model the partitioning of BTEX compounds from the free product phase into the groundwater. In order to use one of these models, samples of free product will be collected and analyzed for mass fraction of BTEX compounds. In wells containing LNAPL, Parsons ES will attempt to collect groundwater samples immediately below LNAPL, where possible.

The chemicals of potential concern for groundwater or surface water at or migrating from IRP Site SS-16 are known to include benzene and arsenic, and likely include other hydrocarbon constituents. However, the BTEX compounds will be the primary focus of this intrinsic remediation study. The Bioplume II model will simulate the degradation of BTEX at the UST site and will be used to predict the concentrations and extent of the contaminant plume in the groundwater over time.

The organic chemicals of concern for the site are expected to migrate downgradient as a dissolved contaminant plume. In addition to the effects of mass transport mechanisms (volatilization, dispersion, diffusion, and adsorption), these dissolved contaminants will likely be removed from the groundwater system by naturally occurring destructive attenuation mechanisms, such as biodegradation. The effects of these fate and transport processes on the dissolved groundwater plume will be investigated using the quantitative groundwater analytical data and the solute-transport model, Bioplume II. Data collection and analysis requirements are discussed in Section 3 of this work plan.

2.2.4 Potential Pathways and Receptors

Potential preferential contaminant migration pathways such as groundwater discharge points and subsurface utility corridors (artificial conduits) will be identified during the field work phase of this project. The primary potential migration paths for contaminants at the site are from the remaining contaminated soils at the site to the groundwater, and from the groundwater to potential receptors via consumption or other use. Shallow groundwater beneath the site is expected to flow southeast toward the Southwest Branch of the Back River. There are no known operating potable or nonpotable water wells located downgradient of the site. Surface drainage by overland flow from the site is primarily directed to storm sewer inlets positioned along Thompson Avenue which then discharge to the Southwest Branch of the Back River. Because the site is on a secured military Base, Base workers and possibly ecological receptors are the probable current receptors of any soil, surface water, or sediment contamination.

The potential for exposure to contaminated water originating from the site through drinking water supplies is low because of the restricted nature of the Base and lack of shallow, potable water wells in the immediate vicinity. The migration of contamination to nearby surface water bodies as a result of IRP Site 16 contamination is possible due to the estimated groundwater flow characteristics in the site vicinity. Potable water for the Base is supplied by the Hampton Roads Sanitary District.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the TS and to evaluate the rates and patterns of intrinsic remediation of fuel-related contaminants, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the TS.

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the groundwater surface in existing monitoring wells;
- Locations of potential groundwater recharge and discharge areas;
- Locations of downgradient wells and their uses;
- Hydraulic conductivity through slug tests, as required;
- Estimate of dispersivity, where possible;
- Stratigraphic analysis of subsurface media;
- Temperature;
- Determination of preferential groundwater migration pathways; and
- Determination of extent and thickness of mobile and residual LNAPL.

Chemical hydrogeologic characteristics to be determined include:

- Dissolved oxygen concentration;
- Specific conductance;
- pH;
- Chemical analysis of free product (if present) to determine mass fraction of BTEX; and

- Additional chemical analysis of groundwater and soil for the parameters listed in Table 3.1.

To obtain these data, soil, groundwater, and free product samples will be collected and analyzed. The following sections describe the procedures that will be followed when collecting additional site-specific data. Drilling, soil sampling, and well point installation will be accomplished using the Geoprobe® system, which is described in Sections 3.1 and 3.2. Procedures to be used to collect soil core samples are described in Section 3.1. Procedures to be used for the installation of new monitoring points are described in Section 3.2. Procedures to be used to sample existing groundwater monitoring wells and newly installed groundwater monitoring points are described in Section 3.3. Procedures used to measure aquifer parameters (e.g., hydraulic conductivity) are described in Section 3.4.

3.1 SOIL SAMPLING

The following subsections describe sample collection techniques, sampling locations at the site, equipment decontamination procedures, site restoration, and management of investigation-derived waste materials.

3.1.1 Sample Collection Using the Geoprobe® System

The Geoprobe® system is a hydraulically powered percussion/probing machine used to advance sampling tools through unconsolidated soils. This system provides for the rapid collection of soil, soil gas, and groundwater samples at shallow depths while minimizing the generation of investigation-derived waste materials. Figure 3.1 is a diagram of the Geoprobe® system. The following sections describe soil sample collection methods, well point installation methods, and decontamination methods using the Geoprobe® system.

Soil samples will be collected using a probe-drive sampler. The probe-drive sampler serves as both the driving point and the sample collection device and is attached to the leading end of the probe rods. To collect a soil sample, the sampler is pushed or driven to the desired sampling depth, the drive point is retracted, which opens the sampling barrel, and the sampler is subsequently pushed into the undisturbed soils. The soil cores are retained within brass, stainless steel, or clear acetate liners inside the sampling barrel. The probe rods are then retracted, bringing the sampling device to the surface. The soil sample can then be extruded from the liners for logging, or the liners can be capped and undisturbed samples submitted to the analytical laboratory for testing.

TABLE 3.1
ANALYTICAL PROTOCOL FOR
GROUNDWATER AND SOIL SAMPLES
IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA

MATRIX	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
WATER		
Total Iron	Colorimetric, HACH Method 8008 (or similar)	F
Ferrous Iron (Fe+2)	Colorimetric, HACH Method 8146 (or similar)	F
Ferric Iron (Fe+3)	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH Method 8034 (or similar)	F
Sulfide	Colorimetric, HACH Method 8131 (or similar)	F
Sulfate	Colorimetric, HACH Method 8051 (or similar)	F
Nitrate	Titrimetric, HACH Method 8039 (or similar)	F
Nitrite	Titrimetric, HACH Method 8507 (or similar)	F
Redox Potential	A2580B, direct reading meter	F
Oxygen	Direct reading meter	F
pH	E150.1/SW9040, direct reading meter	F
Conductivity	E120.1/SW9050, direct reading meter	F
Temperature	E170.1, direct reading meter	F
Alkalinity (Carbonate [CO ₃ -2] and Bicarbonate [HCO ₃ -1])	Titrimetric, HACH Method 8221 (or similar)	F
Carbon Dioxide	CHEMetrics Method 4500	F
Ammonia--Diss. Gas in Water	CHEMetrics Method 4500 NH ₃	F
Nitrite	E300 or SW9056	L
Chloride	E300 or SW9056	L
Sulfate	E300 or SW9056	L
Alkalinity	E150.1	L
Methane	RSKSOP-175	L
Total Organic Carbon	E415.1	L
Aromatic Hydrocarbons (Including Trimethylbenzene and Tetramethylbenzene)	SW8020 (RSKSOP-133)	L
Total Hydrocarbons	SW8015M	L
Volatile Organics	GC/MS method, SW8240	L
Free Product	GC/MSD fuel identification	L
SOIL		
Total Organic Carbon	SW9060	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	SW8020	L
Total Hydrocarbons	SW8015M	L

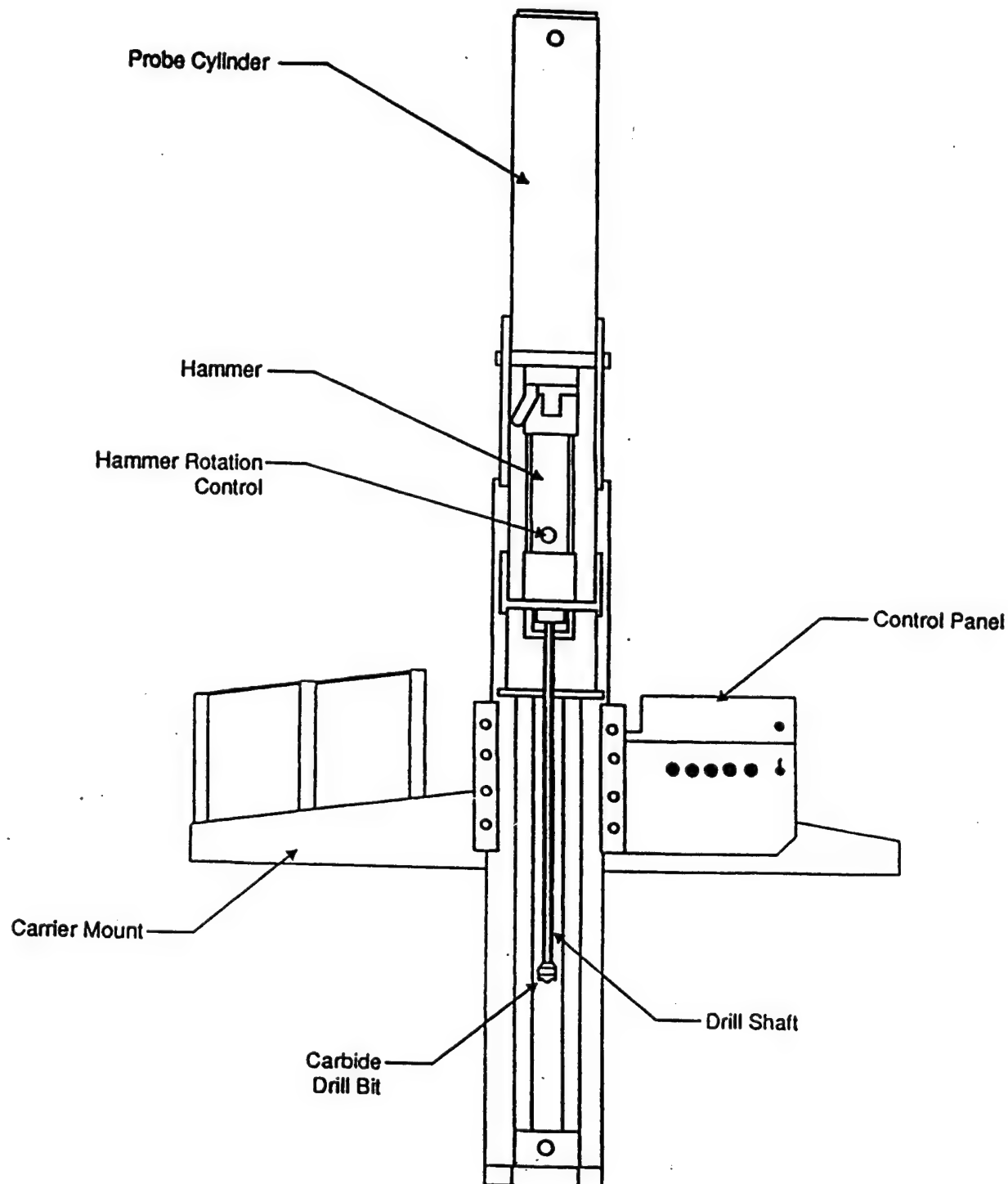


FIGURE 3.1

**CROSS-SECTION
OF GEOPROBE**

IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA



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If the probe-drive sampling techniques described above are inappropriate, inadequate, or unable to efficiently provide sufficient soil samples for the characterization of the site, continuous soil samples will be obtained from conventional core boreholes using a hand auger or similar method judged acceptable by the Parsons ES field scientist. Procedures will be modified, if necessary, to ensure good sample recovery.

The Parsons ES field scientist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure 3.2. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Lithologic description, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Depths of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

Base personnel will be responsible for identifying the location of all utility lines, USTs, fuel lines, or any other underground infrastructure prior to any sampling activities. All necessary digging permits will be obtained by Base personnel prior to mobilizing to the field. Base personnel will also be responsible for acquiring drilling and monitoring point installation permits for the proposed locations. Parsons ES will be responsible for providing trained operators for the Geoprobe®.

3.1.2 Soil Sampling Locations and Required Analyses

Soil samples will be collected at all Geoprobe® and monitoring point installation locations. Table 3.1 presents an analytical protocol for groundwater and soil samples, and Appendix A contains detailed information on the analyses and methods used during this sampling effort. Figure 3.3 identifies nine proposed locations of soil sample collection at IRP Site SS-16. A minimum of two samples will be taken in each hole

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: _____ CONTRACTOR: _____ DATE SPUD: _____
 CLIENT: AFCEE RIG TYPE: _____ DATE CMPL.: _____
 JOB NO.: 722450.20 DRLG METHOD: _____ ELEVATION: _____
 LOCATION: LANGLEY AFB, VIRGINIA BORING DIA.: _____ TEMP: _____
 GEOLOGIST: _____ DRLG FLUID: _____ WEATHER: _____
 COMENTS: _____

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1										
	5										
	10										
	15										
	20										
	25										
	30										
	35										

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

 Water level drilled

FIGURE 3.2

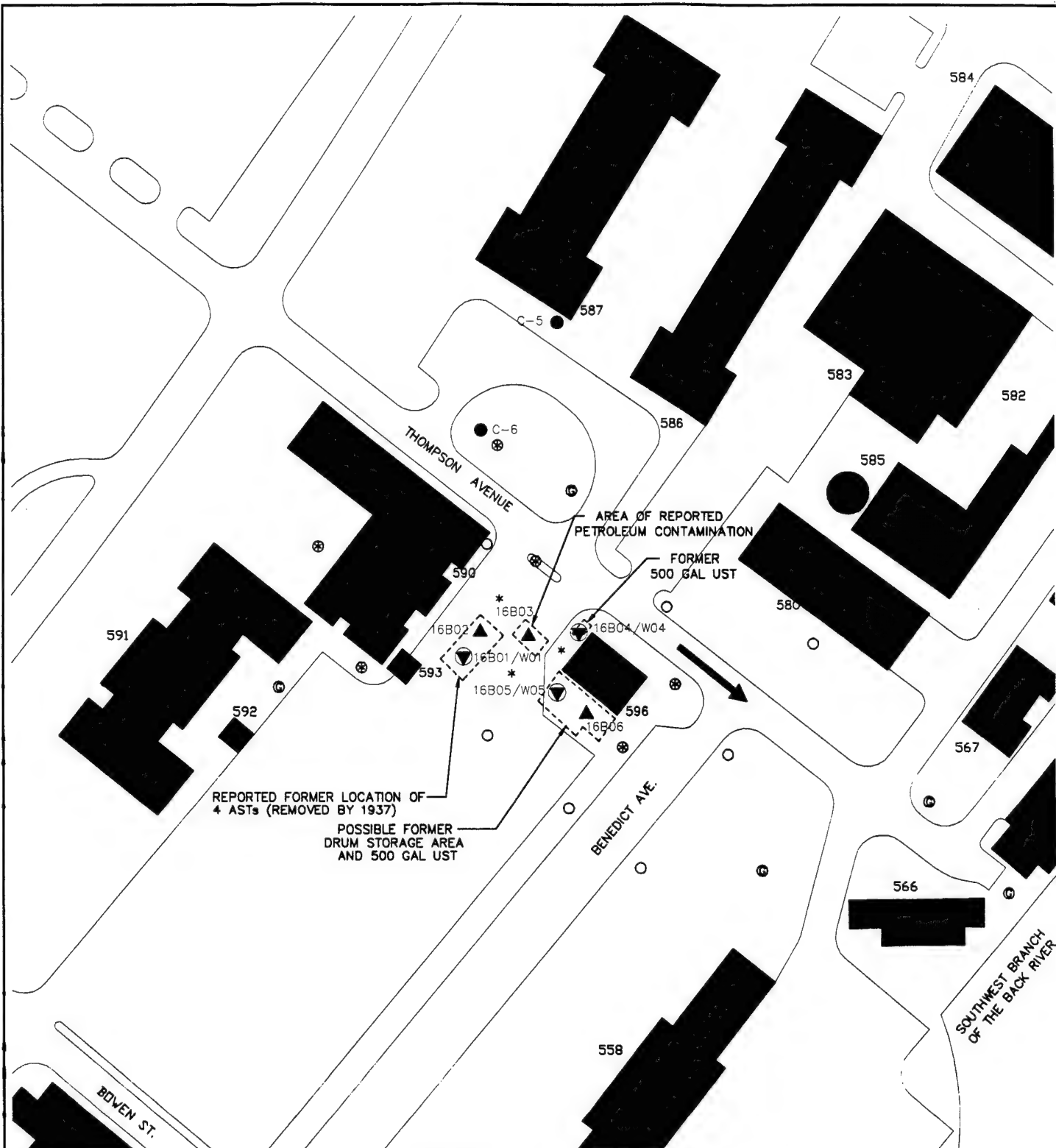
GEOLOGIC BORING LOG

IRP SITE SS-16
 INTRINSIC REMEDIATION TS
 LANGLEY AFB, VIRGINIA



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LEGEND

- SOIL SAMPLING LOCATIONS USED BY W.A.R. IN 1982
- ▲ SOIL BORINGS (LATE 1994)
- ▼ EXISTING WELL LOCATION
- * SOIL SAMPLING LOCATION
- MONITORING POINT (GROUNDWATER SAMPLE ONLY)
- ⊗ MONITORING POINT (SOIL AND GROUNDWATER SAMPLES)
- ⊙ GROUNDWATER GRAB SAMPLE LOCATION
- EXPECTED GROUNDWATER FLOW DIRECTION



0 100 200 FEET

F:\722450\CADD\GEOPROBE, 06/20/95 at 11:37

FIGURE 3.3

PROPOSED GEOPROBE[®] SAMPLING AND/OR MONITORING POINT INSTALLATION LOCATIONS

IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA



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punched: one sample will be taken at the water table, and one will be taken at the depth of maximum BTEX contamination as determined by soil headspace screening. Soil samples will be collected in the vicinity of reported location of the former ASTs, USTs, and area of black fuel staining observed in 1991. Samples also will be taken in the estimated direction of groundwater flow. In addition, soil samples will be collected from at least one location north of the site to confirm the fuel contamination reported by WAR in 1982. Using the available site history information, attempts will be made to sample soils close to WAR coring C-6 (see Figure 3.3). Additional samples and sampling intervals will be collected at the discretion of the Parsons ES scientist.

A portion of each soil sample will be sent to the laboratory for analytical analysis, while another portion of the sample will be utilized to determine soil headspace. Each laboratory soil sample will be placed in an analyte-appropriate sample container and shipped to the analytical laboratory for analysis of total hydrocarbons, aromatic hydrocarbons, and moisture content using the procedures presented in Table 3.1. In addition, samples from uncontaminated locations will be analyzed for total organic carbon (TOC). Each headspace screening sample will be placed in a sealed plastic bag or mason jar and allowed to equilibrate for at least 5 minutes. Soil headspace VOCs then will be determined using an organic vapor meter (OVM), and the results will be recorded by the Parsons ES field scientist.

3.1.3 Datum Survey

The horizontal location and elevation of all soil sampling locations relative to established Base coordinates will be measured by a surveyor. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface at each boring and monitoring point location will be measured to the nearest 0.1 foot relative to USGS msl data. Top of casing elevation of each monitoring point will be measured to the nearest 0.01 foot relative to USGS msl data.

3.1.4 Site Restoration

After sampling is complete, each sampling location will be restored as closely to its original condition as possible. Holes created by the Geoprobe® in sandy soils tend to cave in soon after extraction of the drive sampler. However, any test holes remaining open after extraction of the Geoprobe® rod will be sealed with bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater. Soil sampling using the Geoprobe® creates low volumes of soil waste. Soil

not used for sampling will be scattered around the site or placed in 55-gallon drums provided by the Base, depending on the field screening results. Disposal of containerized soil will be handled by Base personnel. Alternate methods of soil waste disposal will be considered by the Parsons ES field scientist as recommended by Base personnel.

3.1.5 Equipment Decontamination Procedures

Prior to arriving at the site, and between each sampling location, probe rods, tips, sleeves, pushrods, samplers, tools, and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination. All rinseate will be collected either in a decontamination pit or in buckets provided by Parsons ES. A headspace analysis of collected rinseate will be taken by qualified Parsons ES personnel with an OVM. Rinseates with headspace readings less than 5 parts per million on a volume-per-volume basis (ppmv) will be disposed of onsite. A shallow disposal pit may be dug to help recharge and aerate rinseate waters disposed of onsite (at the discretion of Langley AFB personnel). Soils excavated from this disposal pit will be replaced at the end of site characterization activities. Rinseates with headspace readings greater than 5 ppmv will be transferred to 55-gallon drums provided by the Base and later transported and disposed of by Base personnel. Base personnel are responsible for sampling the contents of the drums to identify any hazardous constituents before the drums are transported to an appropriate disposal facility.

Between collection of each soil sample, the sampling barrel will be disassembled and decontaminated with Alconox[®] and potable water, then swabbed with isopropyl alcohol. The barrel will then be rinsed with deionized water and reassembled with new liners. Between uses, the sampling barrel will be wrapped in clean plastic or foil to prevent contamination.

Potable water to be used during equipment cleaning, decontamination, or grouting will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities. Precautions will be taken to minimize any impact to the surrounding area that might result from decontamination operations.

3.2 GROUNDWATER SAMPLING

To further characterize the hydrogeologic conditions of the shallow subsurface, up to 13 groundwater monitoring points may be installed at the site to supplement the existing site monitoring wells. In addition, groundwater grab samples will be collected at up to 5 locations using the Geoprobe® apparatus (Figure 3.3). The following sections describe the proposed sampling locations and intervals, monitoring point installation, grab sampling, monitoring point development, and equipment decontamination procedures.

3.2.1 Monitoring Point Locations and Completion Intervals

The locations of 13 proposed groundwater monitoring points are identified for the site on Figure 3.3. The exact locations for the new monitoring points will be determined based on previous site data and site data generated by Parsons ES through the proposed field activities. Monitoring point locations will be selected to provide hydrogeologic data necessary for successful implementation of the Bioplume II model and to monitor potential fuel hydrocarbon migration from the site. Monitoring point locations will be selected to define three aspects of the site: 1) the extent of contamination, 2) the horizontal and vertical distribution of dissolved BTEX, and 3) the hydrogeology and groundwater flow direction at the site.

Each monitoring point will have a screened interval of 1 meter. Two nested monitoring pairs will each have a point with a shallow screened interval and a point with a deep screened interval. The exact depth of monitoring points will be determined by the Parsons ES field scientist depending on site conditions. The proposed screened intervals of 1 meter for shallow and deep monitoring points will help mitigate the dilution of water samples from potential vertical mixing of contaminated and uncontaminated groundwater in the monitoring point casing, and will give important information on the nature of vertical hydraulic gradients in the area. Adjustments of the depth and length of the screened interval of the monitoring points may be necessary in response to actual aquifer conditions and contaminant distribution identified during Geoprobe® testing.

3.2.2 Monitoring Point Installation Procedures

3.2.2.1 Pre-Placement Activities

All necessary digging, coring, and drilling permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed drilling locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 3.1.1.

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

3.2.2.2 Monitoring Point Materials Decontamination

Monitoring point installation and completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, the well points and tubing will be cleaned prior to use with a high-pressure, steam/hot-water cleaner using approved water. Materials that cannot be cleaned to the satisfaction of the field scientist will not be used.

3.2.2.3 Installation and Materials

This section describes the procedures to be used for installation of monitoring points. Monitoring points will be installed using either 0.375-inch Teflon[®] tubing connected to a 0.5-inch-diameter stainless steel screen, a 0.5-inch inside-diameter (ID)/0.75-inch outside-diameter (OD) polyvinyl chloride (PVC) screen and casing, or a 2-inch ID PVC screen and casing.

3.2.2.3.1 Deep Monitoring Points

The deep monitoring points will be installed in boreholes punched using the Geoprobe[®]. The deep monitoring points will be constructed of a sacrificial drive point attached to a length of 0.5-inch-diameter stainless steel mesh or slotted schedule 40 PVC well screen, which in turn is connected to 0.375-inch Teflon[®] tubing (steel screen) or 0.5-inch PVC casing (PVC screen).

To install the deep monitoring points, the borehole is punched and sampled to several feet above the target depth for the monitoring point. The probe rods are withdrawn from the borehole, and the soil sampler is replaced with the well point assembly. An appropriate length of Teflon[®] tubing is threaded through the probe rods and attached to the well point. The assembly is lowered into the borehole and then driven down to the target depth and sampling zone. The probe rods are removed, leaving the sacrificial tip, screen assembly and tubing behind. The saturated soil formation is likely to cave in around the screen assembly; where this does not occur, silica sand will be emplaced to create a sand pack around the well point. The borehole annular space around the tubing above the sand pack will be filled with annular seal of granular bentonite or grout.

3.2.2.3.2 Shallow Monitoring Points

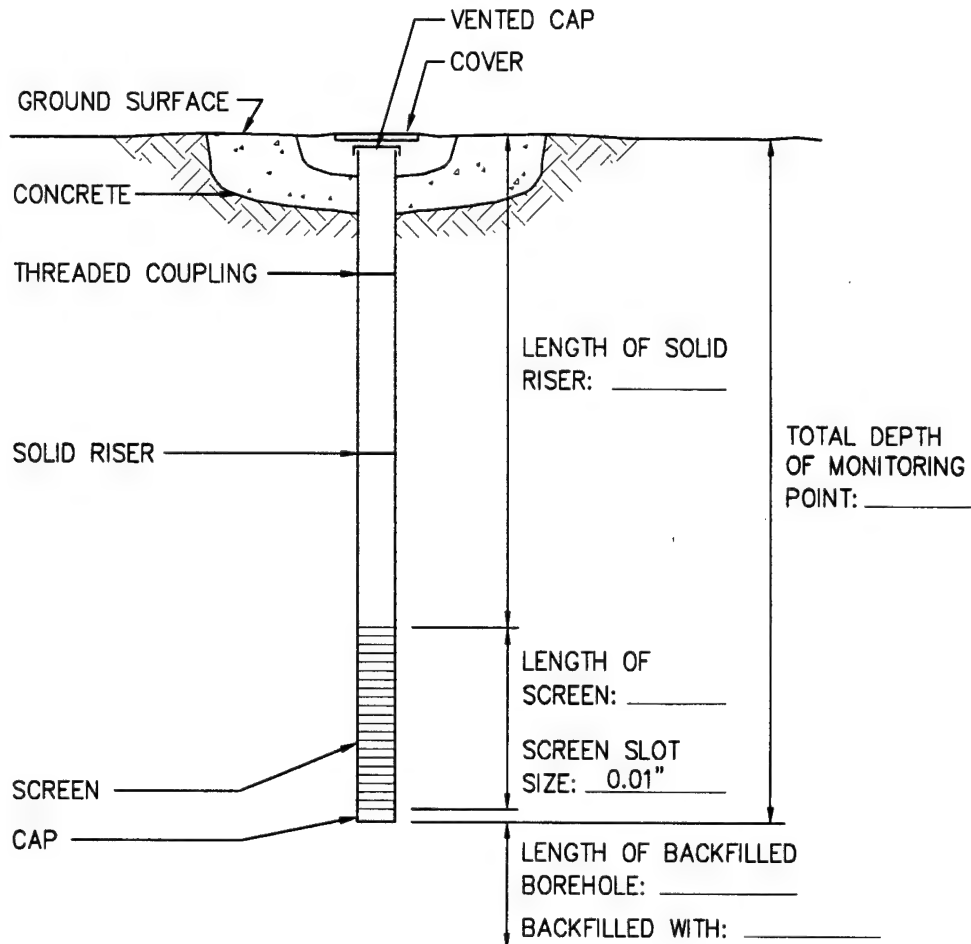
If subsurface conditions permit, shallow monitoring points will be constructed of 0.75-inch OD/0.5-inch ID PVC casing and well screen to provide additional water level information. Approximately 1 meter of factory-slotted screen will be installed for each shallow monitoring point. Up to 5 of the shallow monitoring points will be constructed of 2-inch ID PVC casing and screen to facilitate automatic water level data collection, which employs a 1.5-inch OD submersible pressure transducer. Effective installation of the shallow monitoring points requires that the boreholes remain open upon completion of drilling. Shallow 0.5-inch ID PVC and 2-inch ID PVC monitoring points will be installed by punching and sampling a borehole with the Geoprobe®. Upon removing the rods, the borehole depth will be measured to determine if the hole remains open. If the borehole is open, the 0.5-inch or 2-inch ID PVC casing and screen will be placed at the appropriate depths. Hand augering may be used as an alternate borehole construction method for installation of 2-inch monitoring points. The annular space around the screen will be filled with sand filter pack, and the annulus around the casing will be filled with grout or bentonite. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4). This information will become part of the permanent field record for the site.

Temporary monitoring point screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 0.5 inch or 2-inch. The screens will be factory slotted, with 0.01-inch openings. Monitoring point screens will be placed to sample and provide water level information at or near the water table. Blank monitoring point casing will be constructed of Schedule 40 PVC with an ID of 0.5-inch or 2-inch. All monitoring point casing sections will be flush-threaded; joints will not be glued. The casing at each monitoring point will be fitted with a bottom cap and a top cap constructed of PVC.

If subsurface conditions do not permit the boreholes to stay open (i.e., the formation collapses in the hole), shallow 0.5-inch-ID PVC monitoring points may be installed using the Geoprobe®. If the installation of 0.5-inch PVC monitoring points is not possible or is impractical using the Geoprobe®, monitoring points constructed of 0.375-inch Teflon® (described in Section 3.2.2.3.1) will be utilized. Should 0.5-inch ID PVC shallow monitoring points not be installed, the only data lost will be the water level information for that particular location. The decision to install 0.5-inch ID PVC monitoring points will be made in the field once the open-hole stability of subsurface soils and Geoprobe® equipment can be evaluated. The field scientist will verify and record the total depth of

MONITORING POINT INSTALLATION RECORD

JOB NAME LANGLEY AFB, VIRGINIA MONITORING POINT NUMBER _____
 JOB NUMBER 722450.20 INSTALLATION DATE _____ LOCATION _____
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL _____ SLOT SIZE _____
 RISER DIAMETER & MATERIAL _____ BOREHOLE DIAMETER _____
 GEOPROBE CONTRACTOR _____ ES REPRESENTATIVE _____



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 TOTAL MONITORING POINT DEPTH _____ FEET
 BELOW DATUM.
 GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

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 INTRINSIC REMEDIATION TS
 LANGLEY AFB, VIRGINIA



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the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

3.2.2.4 Monitoring Point Completion

A number of the monitoring points will be completed at or slightly above grade, and steel protective casing will be used to protect the well points from tampering and damage. Where pavement is present, an at-grade cover will be cemented in place using concrete blended into the existing pavement. Where pavement is not present, the protective cover will be raised slightly above the ground surface with a 1-foot square concrete pad that will slope gently away from the cover to facilitate runoff during precipitation events. The number of permanent monitoring points will be determined by the Parsons ES field scientist. The completion of the monitoring points will be similar to those protecting the existing monitoring wells unless otherwise specified by Base personnel.

3.2.2.5 Monitoring Point Abandonment and Site Restoration

After monitoring point installation and sampling is complete, each sampling location will be restored as closely as possible to its original condition. All contaminated development waters and sampling purge waters not disposed of at the site (headspace readings of > 5 ppmv) will remain in 55-gallon drums provided by the Base until transported by Base personnel to the designated waste collection area at the Base.

Those monitoring points not completed with an external casing will be abandoned. The PVC casing and screen or Teflon[®] tubing will be extracted as far as possible and discarded. While holes created by the Geoprobe[®] in sandy soils similar to those found at the Base tend to cave in soon after extraction of the drive rod, any test holes remaining open after extraction of the casing will be sealed with bentonite chips, powder, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater.

3.2.2.6 Monitoring Point Development and Records

The monitoring points will be developed prior to sampling to remove fine sediments from the portion of the formation adjacent to the well point screen. Development will be accomplished using a peristaltic pump provided by Parsons ES. The pump will be attached to the well point, and water will be removed until pH, temperature, specific conductivity, and water clarity (turbidity) stabilize. Monitoring point development will occur a minimum of 24 hours prior to sampling.

Development waters will be collected either in decontamination buckets provided by Parsons ES or 55-gallon barrels provided by Langley AFB. A headspace analysis of development waters will be performed by qualified Parsons ES personnel using a portable OVM. Development waters with headspace readings of less than 5 ppmv will be disposed of onsite. A shallow disposal pit may be dug to help recharge and aerate disposed rinseate waters onsite (at the discretion of Langley AFB personnel). Soils excavated from this disposal pit will be replaced at the end of site characterization activities. Development waters with headspace readings greater than 5 ppmv will be transferred to 55-gallon drums provided by the Base and later transported and disposed of by Base personnel.

A development record will be maintained for each monitoring point. The development record will be completed in the field by the field scientist. Figure 3.5 is an example of a development record used for similar well installations. Development records will include:

- Monitoring point number;
- Date and time of development;
- Development method;
- Monitoring point depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and monitoring point depth; and
- Field analytical measurements, including pH and specific conductivity.

3.2.3 Groundwater Grab Sampling Procedures

The sampling depth and interval will be specified prior to driving the Geoprobe® pushrod into the ground. The Parsons ES field scientist will verify the sampling depth by measuring the length of each pushrod prior to insertion into the ground. A drive tip fitted with a slotted steel screen will be placed on the tip of the pushrod, and the rod will be

MONITORING POINT DEVELOPMENT RECORD

Page__ of__

Job Number: 722450.20

Job Name: Langley AFB, Virginia

Location: _____

By _____

Date _____

Well Number _____

Measurement Datum _____

Pre-Development Information

Time (Start): _____

Water Level: _____

Total Depth of Well: _____

Water Characteristics

Color _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material _____
pH _____ Temperature(°F °C) _____
Specific Conductance(μS/cm) _____

Interim Water Characteristics

Gallons Removed _____

pH _____

Temperature (°F °C) _____

Specific Conductance(μS/cm) _____

Post-Development Information

Time (Finish): _____

Water Level: _____

Total Depth of Well: _____

Approximate Volume Removed: _____

Water Characteristics

Color _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material _____
pH _____ Temperature(°F °C) _____
Specific Conductance(μS/cm) _____

Comments: _____

FIGURE 3.5

MONITORING POINT DEVELOPMENT RECORD

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LANGLEY AFB, VIRGINIA



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pushed into the ground using the Geoprobe[®] apparatus. After reaching the desired depth, the pushrod will be raised 1 to 2 feet to expose the screen and to allow water to percolate into the end of the hollow pushrod. Water samples will be collected from water entering the downhole, slotted end of the pushrod through the screen with a peristaltic pump. The groundwater sample will be acquired as described in Section 3.3.2.

3.2.4 Monitoring Point Location and Datum Survey

The location and elevation of the well points will be surveyed soon after completion. The horizontal location will be measured relative to established Base coordinates. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface adjacent to the protective casing will be measured to the nearest 0.1 foot relative to the USGS msl datum. The top of casing elevation of the monitoring points constructed with PVC casing will be measured to the nearest 0.01 foot relative to USGS msl datum. Measuring point elevation, such as top of casing, will not be measured for well points constructed with a flexible tubing riser because water levels cannot be measured through the tubing.

3.2.5 Water Level Measurements

Water levels will be measured at existing wells and monitoring points (where possible) to determine the groundwater flow direction and hydraulic gradient in vicinity of the site. This information is required to accurately estimate the movement (velocity and direction) of groundwater and contaminants in the shallow saturated zone. Water levels can be measured manually using a hand-held water level indicator or automatically using an electronic data-logger instrument and pressure transducer system.. Automatic data collection is preferred in situations where water levels fluctuate continuously over time, such as in the reported tidally influenced surficial aquifer at the Base.

3.2.5.1 Manual Water Level Measurements

Using a hand-held water level indicator, water levels at monitoring wells and monitoring points will be measured (where possible) within a short time period so that the water level data are comparable. The depth to water below the measurement datum will be measured to the nearest 0.01 foot using an electric water level probe. These measurements will be used to verify the automatic water level data as described in the following section.

3.2.5.2 Automatic Water Level Measurements

Automatic water level collection is accomplished by measuring the water level at selected wells over time using a data-logger instrument and pressure transducer system. Water levels will be measured in a combination of up to seven existing wells and 2-inch ID monitoring points. Because water level collection will be completed on existing wells in addition to monitoring points, it will be assumed that the wells were properly developed and have established adequate communication with the surficial aquifer. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results; water level data will not be collected at wells with free product. The pressure transducers and any other downhole equipment will be decontaminated prior to and immediately after the collection of water level data using the procedures described in Section 3.3.1.1.

A barometric pressure transducer will be used to measure changes in atmospheric pressure during automatic water level data collection. Changes in barometric pressure can cause a reciprocal response (called barometric efficiency) in water levels of unconfined and confined aquifers. These data will be used to evaluate the barometric efficiency of the surficial aquifer in the study area.

3.2.5.2.1 Equipment

The following equipment will be used to perform automatic water level measurements:

- Electric water level indicator;
- Pressure transducers/sensors;
- Field logbook/forms; and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger[®], In-Situ, Inc. Model SE2000, or equivalent.)

3.2.5.2.2 Data Collection Procedures

The following paragraphs describe procedures to be followed during the collection of automatic water level data.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open each well to be monitored. Where wells are equipped with water-tight caps, the well should be unsealed at least 24 hours prior to testing to allow the water

level to stabilize. The protective casing will remain locked during this time to prevent vandalism.

3. Lower a decontaminated pressure transducer into each well and allow the displaced water to stabilize at least 24 hours prior to testing.
4. Complete logbook entries for:
 - Borehole/well numbers,
 - Water level collection team members,
 - Climatic data,
 - Ground surface elevations,
 - Top of well casing elevations,
 - Identification of measuring equipment being used,
 - Static water level in each well/monitoring point, and
 - Date and time corresponding to each static water level measurement.
4. Measure the static water level in each well to the nearest 0.01 foot using a hand-held water level indicator. Enter the reference water level (i.e., depth to water) for each well in the data logger.
5. Program the data logger to measure the water level in each well every 30 minutes at a minimum.
6. Turn on the data logger. Follow the owner's manual for proper operation of the data logger.
7. Terminate data recording after accumulating at least 24 hours of data. Data collection data may be extended beyond 24 hours at the discretion of the Parsons ES field scientist.

3.3 GROUNDWATER SAMPLING

This section describes the scope of work required for collection of groundwater quality samples. Samples will be collected from existing monitoring wells (i.e., wells W01, W04, and W05), newly installed groundwater monitoring points, and grab sample locations (Figure 3.3). A peristaltic pump with dedicated tubing will be used to collect groundwater samples. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Sampling will be conducted by qualified scientists and technicians from Parsons ES who are trained in the conduct of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference. The following activities will occur during groundwater sampling:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well/point integrity including:
 - Protective cover, cap, and lock,
 - External surface seal and pad,
 - Monitoring point stick-up, cap, and datum reference, and
 - Internal surface seal;
- Groundwater sampling, including
 - Water level and, if present, product thickness measurements,
 - Visual inspection of sample water,
 - Monitoring point casing evacuation, and
 - Sample collection;
- Sample preservation and shipment, including
 - Sample preparation,

-Onsite measurement of physical parameters, and

-Sample labeling;

- Completion of sampling records: and
- Sample disposition.

Detailed groundwater sampling and sample handling procedures are presented in following sections.

3.3.1 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.3.1.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the Geoprobe® soil sampling tool, water level probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with isopropyl alcohol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling record (Figure 3.6).

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and

GROUNDWATER SAMPLING RECORD

SAMPLING LOCATION _____

SAMPLING DATE(S) _____

MONITORING WELL _____

(number)

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: _____, 19__ a.m./p.m.

SAMPLE COLLECTED BY: _____ of _____

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED:

☐ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT

STEEL CASING CONDITION IS: _____

INNER PVC CASING CONDITION IS: _____

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 ☐

EQUIPMENT CLEANED BEFORE USE WITH _____

Items Cleaned (List): _____

2 ☐

PRODUCT DEPTH _____ FT. BELOW DATUM

Measured with: _____

WATER DEPTH _____ FT. BELOW DATUM

Measured with: _____

3 ☐

WATER-CONDITION BEFORE WELL EVACUATION (Describe):

Appearance: _____

Odor: _____

Other Comments: _____

4 ☐

WELL EVACUATION:

Method: _____

Volume Removed: _____

Observations: Water (slightly - very) cloudy

Water level (rose - fell - no change)

Water odors: _____

Other comments: _____

FIGURE 3.6

GROUNDWATER SAMPLING RECORD

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sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the permanent record of the sampling event.

3.3.1.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of dissolved oxygen (DO), pH, electrical conductivity, temperature, redox potential, sulfate, nitrate, ferrous iron (Fe^{2+}), and other field parameters listed on Table 3.1.

3.3.2 Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and through cross-contamination due to insufficient cleaning of equipment between wells and monitoring points. To prevent such contamination, the water level probe and cable used to determine static water levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.1.1. Dedicated tubing will be used at each well or monitoring point developed, purged, and/or sampled with the peristaltic pump. Dedicated, disposable bailers may be used on the 2-inch ID existing wells. Any nondisposable bailers will be decontaminated according to procedures listed in Section 3.3.1.1. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile or latex gloves will be worn by sampling personnel each time a different well or monitoring point is sampled. The following paragraphs present the procedures to be followed for groundwater sample collection from groundwater monitoring wells and monitoring points. These activities will be performed in the order presented below. Exceptions to this procedure will be noted in the field scientist's field notebook.

3.3.2.1 Preparation of Location

Prior to starting the sampling procedure, the area around the existing wells and new monitoring points will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well/point.

3.3.2.2 Water Level and Total Depth Measurements

Prior to removing any water from the monitoring well or monitoring point, the static water level will be measured. An electric water level probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring well/point, and the depth will be measured to the nearest 0.01 foot. If free-phase product (LNAPL) is present, the total depth of the well from installation records will be used to avoid excessive contamination of the water level probe and cord. Based on these measurements, the volume of water to be purged from the monitoring well/point will be calculated. If free-phase product is encountered, the thickness of the product will be measured with an oil/water interface probe.

3.3.2.3 Monitoring Well/Point Purging

The volume of water contained within the monitoring well/point casing at the time of sampling will be calculated, and three times the calculated volume will be removed from the well/point. A peristaltic pump will be used for monitoring well and monitoring point purging, depth permitting, and either a Waterra[®] inertial pump or a bailer will be used to purge all monitoring points in which a peristaltic pump will not work. All purge water will be collected either in a decontamination pit or in buckets provided by Parsons ES. A headspace analysis of collected purge water will be performed by qualified Parsons ES personnel with a portable OVM. Purge waters with headspace readings less than 5 ppmv will be disposed of onsite. A shallow, disposal pit may be dug to help recharge and aerate disposed purge waters onsite (at the discretion of Langley AFB personnel). Soils excavated from this disposal pit will be replaced at the end of site-characterization activities. Purge waters with headspace readings greater than 5 ppmv will be transferred to 55-gallon drums provided by the Base and later transported and disposed of by Base personnel.

If a monitoring well/point is evacuated to a dry state during purging, the monitoring well/point will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the monitoring well/point to obtain the necessary sample quantity. Sample compositing or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

3.3.2.4 Sample Extraction

Dedicated high-density polyethylene (HDPE) tubing and a peristaltic pump will be used to extract groundwater samples from monitoring wells/points whenever depth to groundwater permits; otherwise, a Waterra[®] inertial pump or bailer will be used. A peristaltic pump will be used to extract groundwater samples from the grab sampling locations. Prior to sample collection, groundwater will be purged until dissolved oxygen and temperature readings have stabilized. The tubing, pump, or bailer will be lowered through the casing into the water gently to prevent splashing. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be collected, analyzed, and disposed of as outlined in Section 3.3.2.3.

3.3.3 Onsite Groundwater Parameter Measurement

As indicated in Table 3.1, many of the groundwater chemical parameters will be measured onsite by Parsons ES staff. Some of the measurements will be made with direct-reading meters, while others will be made using a HACH[®] portable colorimeter in accordance with specific HACH[®] analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of Alconox[®] and water, and rinsing with isopropyl alcohol and deionized water to prevent interference or cross-contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric method, the analysis will be repeated by diluting the groundwater sample with double-distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps. These waste containers will be clearly labeled as to their contents and carefully stored for later transfer by Base personnel to the approved disposal facility.

3.3.3.1 Dissolved Oxygen Measurements

DO measurements will be made before and immediately following groundwater sample acquisition using a meter with a downhole oxygen sensor or a sensor in a flow-through

cell. When DO measurements are taken in monitoring wells/points that have not yet been sampled, the existing monitoring wells/points will be purged until DO levels stabilize.

3.3.3.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a flow-through cell or a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded in the groundwater sampling record (Figure 3.6).

3.3.3.3 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by experienced Parsons ES scientists via titrimetric analysis using EPA-approved HACH® Method 8221 (0 to 5,000 milligrams per liter [mg/L] as calcium carbonate) or a similar method. Alkalinity of the groundwater sample will also be measured in the laboratory using EPA Method 310.1.

3.3.3.4 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the field by experienced Parsons ES scientists via colorimetric analysis using a HACH® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with HACH® Method 8039 (0 to 30.0 mg/L NO₃). Nitrite concentrations in groundwater samples will be analyzed after preparation with EPA-approved HACH® Method 8507 (0 to 0.35 mg/L NO₂) or a similar method. Nitrate and nitrite-nitrogen samples will also be analyzed by the analytical laboratory using EPA method 353.1.

3.3.3.5 Carbon Dioxide Measurements

Carbon dioxide concentrations in groundwater will be measured in the field by Parsons ES scientists via titrimetric analysis using HACH® Method 8223 (0 to 250 mg/L as CO₂). Sample preparation and disposal procedures are the same as outlined at the beginning of Section 3.3.3.

3.3.3.6 Sulfate and Sulfide Sulfur Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is resultant after sulfate reduction. A Parsons ES scientist will measure sulfate and sulfide concentrations via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. EPA-approved HACH® Methods 8051 (0 to 70.0 mg/L SO₄) or similar and 8131 (0.60 mg/L S²⁻) or similar will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively. Sulfate concentrations will also be analyzed by the analytical laboratory using method E300 or SW9056.

3.3.3.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different ionic states of iron can affect the redox potential of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. HACH® Method 8008 (or similar) for total soluble iron (0 to 3.0 mg/L Fe³⁺ + Fe²⁺) and HACH® Method 8146 (or similar) for ferrous iron (0 to 3.0 mg/L Fe²⁺) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.3.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a HACH® DR/700 Portable Colorimeter. EPA-approved HACH® Method 8034 (0 to 20.0 mg/L) or similar will be used for quantitation of manganese concentrations. Sample preparation and disposal procedures are outlined earlier in Section 3.3.3.

3.3.3.9 Redox Potential

The reduction/oxidation (redox) potential of groundwater is an indication of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater usually are biologically mediated; therefore, the redox potential of a

groundwater system depends upon and influences rates of biodegradation. Redox potential can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a groundwater sample taken inside the contaminant plume should be somewhat less than that taken upgradient or cross-gradient from the plume.

The redox potential of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. Therefore, this parameter will be measured in the field in a flow-through cell or in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis.

3.4 SAMPLE HANDLING FOR LABORATORY ANALYSIS

This section describes the handling of samples from the time of sampling until the samples are delivered to the fixed-base laboratory. For this study, Evergreen Analytical Laboratories, Inc. (EAL) of Wheatridge, Colorado will provide fixed-base analytical laboratory support.

3.4.1 Sample Preservation

All necessary sample containers will be provided by the laboratory, and necessary chemical preservatives will be pre-placed in the sample containers. Samples will be prepared for transportation to EAL by placing the samples in a cooler containing ice to maintain a shipping temperature of 4 degrees centigrade (°C). Samples will be delivered to the analytical laboratory via overnight courier so that all sample holding times are met.

3.4.2 Sample Containers and Labels

Sample containers and appropriate container lids will be provided by the laboratory (see Appendix A). The sample containers will be filled as described in Section 3.3.3.2.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;

- Sample type (e.g., groundwater, soil);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

3.4.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the laboratory. The following packaging and labeling procedures will be used:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by overnight courier to the analytical laboratory. Shipping will occur as soon as possible after sample acquisition.

3.4.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the analytical laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sampling contractor after sample deliver to the analytical laboratory, and the other two copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collectors' printed names and signatures;
- Date and time of collection;

- Place and address of collection;
- Sample matrix;
- Chemical preservatives added;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container, but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

3.4.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
 - Sample appearance, and
 - Sample odor;
- Weather conditions;
- Water level prior to purging (groundwater samples, only);

- Total monitoring well/point depth (groundwater samples, only);
- Sample depth (soil samples, only);
- Purge volume (groundwater samples, only);
- Water level after purging (groundwater samples, only);
- Monitoring well/point condition (groundwater samples, only);
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity (groundwater samples, only); and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form. Figure 3.6 is an example of the groundwater sampling record. Soil sampling information will be recorded in the field log book.

3.4.6 Laboratory Analyses

Laboratory analyses will be performed on all groundwater and soil samples and on the QA/QC samples described in Section 5. The analytical methods for this sampling event are listed in Table 3.1. Prior to sampling, arrangements will be made with the analytical laboratory to provide a sufficient number of analyte-appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with EPA protocol or those specified in Appendix A of this plan.

EAL personnel will provide and prepare necessary sample bottles for QC analysis. For samples requiring chemical preservation, preservatives will be added to containers by EAL. Containers, ice chests with adequate padding, and cooling media may be sent by the laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the mobile laboratory.

3.5 AQUIFER TESTING

Slug tests will be conducted on selected existing wells to estimate the hydraulic conductivity of unconsolidated sand and clay deposits at the site. This information is required to accurately estimate the velocity of groundwater and contaminants in the

shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft²/day). Slug testing can be performed using either a rising head or a falling head test; at this site, both methods will be used in sequence.

3.5.1 Definitions

Hydraulic Conductivity (K). A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.

Transmissivity (T). A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.

Slug Test. Two types of testing are possible: rising head and falling head tests. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.

Rising Head Test. A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.

Falling Head Test. A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.5.2 Equipment

The following equipment will be used to conduct a slug test:

- Teflon[®], PVC, or metal slugs;
- Nylon or polypropylene rope;

- Electric water level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger[®], In-Situ, Inc. Model SE1000B, or equivalent.)

3.5.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Because hydraulic testing will be completed on existing wells, it will be assumed that the wells were properly developed and that water levels have stabilized. Slug testing will proceed only after multiple water level measurements over time show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results; slug tests will not be performed on wells with free product. The field scientist will determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.3.1.1.

3.5.4 Falling Head Test

The falling head test is the first step in the two-step slug testing procedure. The following steps describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are equipped with water-tight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the aquifer slug test data form (Figure 3.7) with entries for:

AQUIFER SLUG TEST DATA SHEET

Location: _____ Client: AFCEE Well No. _____
 Job No.: 722450.20 Field Scientist _____ Date _____
 Water Level _____ Total Well Depth _____
 Measuring Datum _____ Elevation of Datum _____
 Weather _____ Temp _____
 Comments _____

[illegible]**FIGURE 3.7**

AQUIFER TEST DATA FORM

IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA



**PARSONS
ENGINEERING SCIENCE, INC.**

ATLANTA, GEORGIA

- Borehole/well number,
 - Project number,
 - Project name,
 - Aquifer testing team,
 - Climatic data,
 - Ground surface elevation,
 - Top of well casing elevation,
 - Identification of measuring equipment being used,
 - Page number,
 - Static water level, and
 - Date.
4. Measure the static water level in the well to the nearest 0.01 foot.
 5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
 6. Lower the decontaminated slug into the well to just above the water level in the well.
 7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.
 8. Terminate data recording when the water level stabilizes in the well. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.
3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV™ and the method of Hvorslev (1951) for confined aquifers or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions.

SECTION 4

REMEDIAL OPTION EVALUATION AND TS REPORT

Upon completion of field work, the Bioplume II numerical groundwater model will be used to determine the fate and transport of fuel hydrocarbons dissolved in groundwater at IRP Site SS-16. Based upon model predictions of contaminant concentration and distribution through time, and upon potential exposure pathways, the potential risk to human health and the environment will be assessed. If it is shown that intrinsic remediation of BTEX compounds at the site is sufficient to reduce the potential risk to human health and the environment to acceptable levels (e.g., state groundwater standards), Parsons ES will recommend implementation of the intrinsic remediation option. If intrinsic remediation is chosen, Parsons ES will prepare a site-specific, long-term monitoring plan that will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If the intrinsic remediation remedial option is deemed inappropriate for use at this site, institutional controls such as groundwater or land use restrictions will be evaluated to determine if they will be sufficient to reduce the risk to human health and the environment to acceptable levels. If institutional controls are inappropriate, remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate remedial options will be recommended. Potential remedial options include, but are not limited to, free product recovery, groundwater pump and treat, enhanced biological treatment, bioventing, bioslurping, and *in situ* reactive barrier walls. The reduction in dissolved BTEX that should result from remedial activities will be used to produce a new input file for the Bioplume II model. The model will then be used to predict the BTEX plume (and risk) reduction that should result from remedial actions.

Upon completion of Bioplume II modeling and remedial option selection, a TS report detailing the results of the modeling and remedial option selection will be prepared. This report will follow the outline presented in Table 4.1 and will contain an introduction, site descriptions, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the recommended remedial approach for IRP Site SS-16. This report will also present the results of the site characterization

TABLE 4.1
EXAMPLE TS REPORT OUTLINE
IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA

INTRODUCTION

SITE DESCRIPTION

- Drilling, Soil Sampling, and Monitoring Well Installation
- Groundwater Sampling
- Aquifer Testing
- Surveying

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

- Surface Features
- Regional Geology and Hydrogeology
- Site Geology and Hydrogeology

NATURE AND EXTENT OF CONTAMINATION

- Source of Contamination
- Soil Chemistry
- Groundwater Chemistry

GROUNDWATER MODEL

- General Overview and Model Description
- Conceptual Model Design and Assumptions
- Initial Model Setup
- Model Calibration
- Sensitivity Analysis
- Model Results
- Conclusions and Discussion

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

- Remedial Alternative Evaluation Criteria
- Factors Influencing Alternatives Development
- Brief Description of Remedial Alternatives
- Evaluation of Alternatives
- Recommended Remedial Approach

LONG-TERM MONITORING PLAN

- Overview
- Monitoring Networks for Groundwater
- Groundwater Sampling

CONCLUSIONS AND RECOMMENDATIONS

REFERENCES

APPENDICES

activities described herein and a description of the Bioplume II model developed for this site.

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field, and trip blanks; decontamination of all equipment that contacts the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to EAL for analysis will be labeled clearly to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of 4°C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate groundwater and soil samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

Soil and groundwater samples collected with the Geoprobe® sampler should provide sufficient volume for some duplicate analyses. Refer to Table 3.1 and Appendix A for further details on sample volume requirements.

One rinseate sample will be collected for every 10 or fewer groundwater samples collected from existing wells and newly installed monitoring points. Because disposable bailers may be used for this sampling event, the rinseate sample may consist of a sample of distilled water poured into a new disposable bailer and subsequently transferred into a

TABLE 5.1
QA/QC SAMPLING PROGRAM
IRP SITE SS-16
INTRINSIC REMEDIATION TS
LANGLEY AFB, VIRGINIA

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytical Methods
Duplicates/Replicates	2 Ground Water and 2 Soil Samples (10%)	VOCs, TPH
Rinseate Blanks	2 Samples (10% of Ground Water Samples)	VOCs
Field Blanks	2 Samples (5% of Ground Water Samples)	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)

sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs only.

A field blank will be collected for every 20 or fewer groundwater samples (both from the groundwater monitoring point and the existing groundwater monitoring well sampling events) to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

A trip blank will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory. A trip blank will be transported inside each cooler which contains samples for VOC analysis. Trip blanks will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by EAL and monitored for the analytical methods used.

SECTION 6

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APPENDIX A

**CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING
REQUIREMENTS FOR GROUNDWATER SAMPLES**

Appendix A - Soil, Soil Gas, and Groundwater Analytical Protocol

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Volatile organics	Gas chromatography/mass spectrometry method SW8240.	Handbook method	Data is used to determine the extent of chlorinated solvent and aromatic hydrocarbon contamination, contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon®-lined cap; cool to 4°C	Fixed-base
Soil	Aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil; the rate of release of petroleum contaminants from the source into groundwater is dependent (in part) on the amount of TOC in the vadose zone soil	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base

Appendix A - Soil, Soil Gas, and Groundwater Analytical Protocol (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Soil	Grain size distribution	ASTM D422	Procedure provides a distribution of grain size by sieving	Data are used to infer hydraulic conductivity of aquifer, and are used in calculating sorption of contaminants	One time during life of project	Collect 250 g of soil in a glass or plastic container; preservation is unnecessary	Fixed-base
Soil gas	Oxygen content of soil gas	Electrochemical oxygen meter operating over the range of 0–25 percent of oxygen in the soil gas sample	The concentration of soil gas oxygen is often related to the amount of biological activity, such as the degradation of petroleum hydrocarbons; soil gas oxygen concentrations may decrease to the point where anaerobic pathways dominate	Data are used to understand the oxygen concentration gradient with depth and to determine the presence or absence of aerobic degradation processes	Each sampling round	N/A	Field
Soil gas	Carbon dioxide content of soil gas	Nondispersive infrared instrument operating over the range of approximately 0.1–15 percent	Soil gas carbon dioxide may be produced by the degradation of petroleum hydrocarbons	Data used to understand the carbon dioxide concentration gradient with depth and to infer the biological degradation of petroleum contaminants	Each sampling round	N/A	Field

Appendix A - Soil, Soil Gas, and Groundwater Analytical Protocol (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil gas	Methane content of soil gas	Total combustible hydrocarbon meter using a platinum catalyst with a carbon trap, and operating in the low parts per million volume (ppmv) range	Methane is a product of the anaerobic degradation of petroleum hydrocarbons	Soil gas methane can be used to locate contaminated soil and to determine the presence of anaerobic processes; see discussion of data use for methane in water	Each sampling round	N/A	Field
Soil gas	Fuel hydrocarbon vapor content of soil gas	Total combustible hydrocarbon meter operating over a wide ppmv range	Soil gas hydrocarbons indicate the presence of these contaminants in the soil column	Data used to understand the petroleum hydrocarbon concentration gradient with depth and to locate the most heavily contaminated soils	Each sampling round	N/A	Field
Water	Iron (II) (Fe^{+2})	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Water	Iron (II) (Fe^{+2})	Colorimetric HACH Method # 8146	Alternate method; field only	Same as above	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Total Iron	Colorimetric HACH Method # 8008	Field only		Each sampling round	Collect 100mL of water in a glass container	Field
Water	Manganese	Colorimetric HACH Method # 8034	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl ⁻ C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Chloride	HACH Chloride test kit model 8-P	Silver nitrate titration	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field

Appendix A - Soil, Soil Gas, and Groundwater Analytical Protocol (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen <i>in situ</i>	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Water	Temperature	E170.1	Field only	Well development	Each sampling round	N/A	Field
Water	Alkalinity	HACH Alkalinity test kit model AL AP MG-L	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 100mL of water in glass container	Field
Water	Alkalinity	A2320, titrimetric; E150.1, colorimetric	Handbook method	Same as above	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base

Appendix A - Soil, Soil Gas, and Groundwater Analytical Protocol (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Nitrate (NO ₃ ⁻¹)	HACH method # 8039 for high range method # 8192 for low range	Colorimetric	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Nitrite (NO)	HACH method #8040	Colorimetric	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Sulfate (SO ₄ ⁻²)	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO ₄ ⁻²)	HACH method # 8051	Colorimetric	Same as above	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Water	Dissolved sulfide (S ⁻²)	HACH method # 8131	Colorimetric	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis	Each sampling round	Collect 100 mL of water in a glass container; analyze immediately	Field
Water	Redox potential	A2580 B, direct reading meter	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100-250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

Appendix A - Soil, Soil Gas, and Groundwater Analytical Protocol (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Methane; carbon dioxide	RSKSOP-175 modified to analyze water samples for methane and carbon dioxide by headspace sampling with dual thermal conductivity and flame ionization detection (also, see reference in note 10)	Method published and used by the U.S. Environmental Protection Agency (EPA) Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis); a redox potential measurement of less than -200 mV could be indicative of methanogenesis and should be followed by the analysis referenced here; the presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect water samples in 40 mL volatile organic analysis (VOA) vials with butyl gray/Teflon-lined caps; cool to 4°C	Fixed-base Laboratory
	Ethane, ethene	RSKSOP-175 (cont'd)	Ethane and ethene are analyzed in addition to the other analytes only if chlorinated hydrocarbons are suspected of undergoing biological transformation	Ethane and ethene are products of the biotransformation of chlorinated hydrocarbons under anaerobic conditions. The presence of these chemicals may indicate that anaerobic degradation is occurring			

Appendix A - Soil, Soil Gas, and Groundwater Analytical Protocol (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Carbon dioxide	HACH test kit model CA-23	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Aromatic hydrocarbons (BTEX, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX, which is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base

Appendix A - Soil, Soil Gas, and Groundwater Analytical Protocol (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation; data also used to infer presence of an emulsion or surface layer of petroleum in water sample, as a result of sampling	One time per year or as required by regulations	Volatile hydrocarbons--collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons--collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base

Appendix A - Soil, Soil Gas, and Groundwater Analytical Protocol (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Dissolved organic carbon (DOC) (optional)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L.	An indirect index of microbial activity	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base

Appendix A - Soil, Soil Gas, and Groundwater Analytical Protocol (Concluded)

NOTES:

1. "HACH" refers to the HACH Company catalog, 1995.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to *Robert S. Kerr (Environmental Protection Agency Laboratory) Standard Operating Procedure*.
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.

APPENDIX B

**AVAILABLE SOIL AND GROUNDWATER ANALYTICAL RESULTS AND
SOIL BORING LOGS**

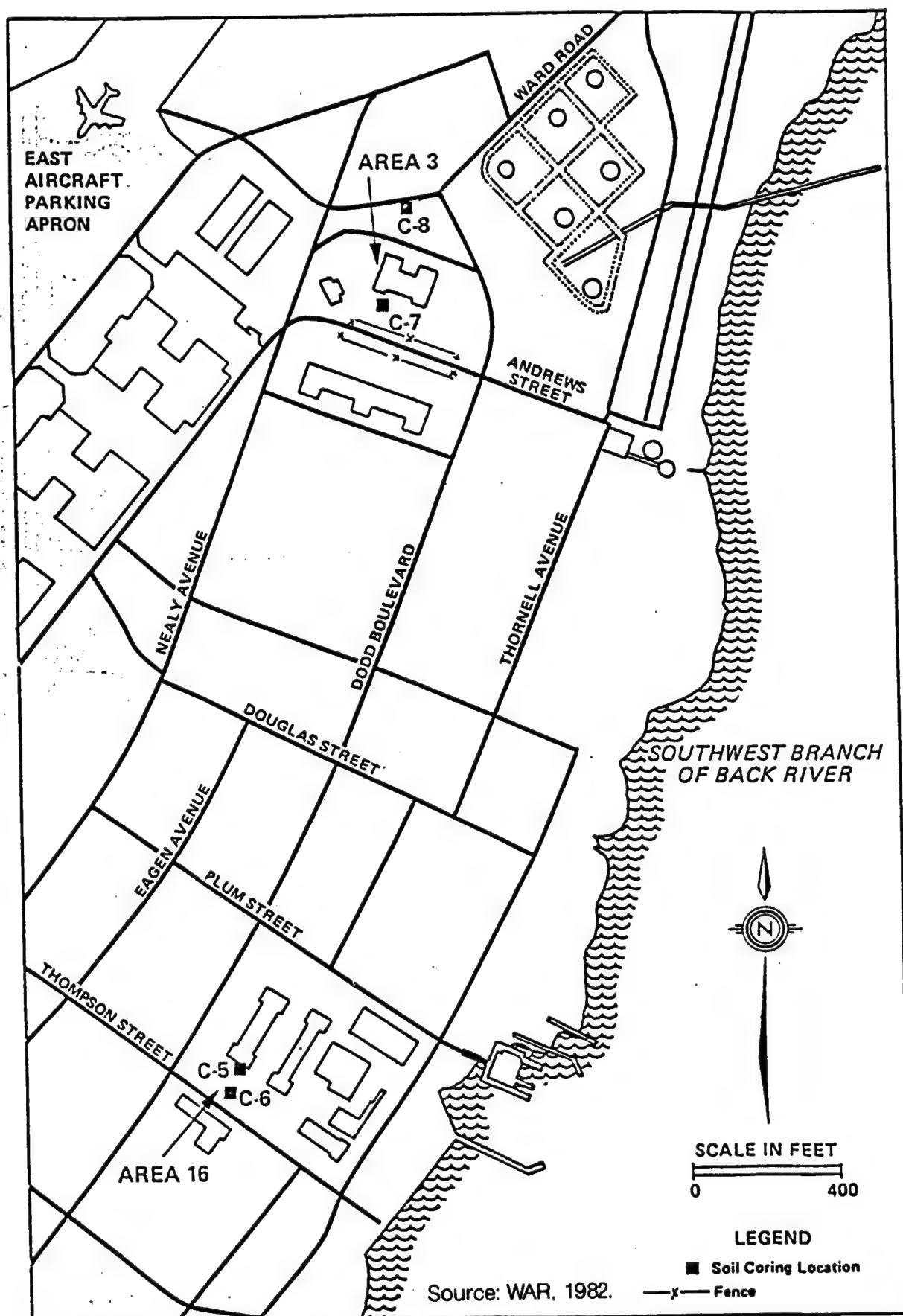


FIGURE 8. Soil Coring Locations for Areas of Potential Fuel Contamination (Areas 16 and 3), Langley Air Force Base, October 1981

Table 7. Results of Analyses of Soil Cores from the Suspected Fuel-Saturated Areas, Langley AFB, October 1981

Location	Site	Depth (ft)	Odor	Volatile Hydrocarbons by GC (mg/kg)	Hydrocarbon by Freon Extraction (mg/kg)		
					No Cleanup	Silica Gel Cleanup	
Area 3	C-7	2	Soil	<1	140	<30	<30
		4	Soil	<1	180	<30	<30
		6	Soil	20	230	<30	<30
	C-8	2	Soil	30	270†	NA**	NA**
		4	H ₂ S	35	36†	NA	NA
Area 4	C-3	6	Soil	10	<30	NA	NA
		2	Soil	4	470	<30	<30
		2	Soil	<1	<30	NA	NA
	C-4	4	Soil	2	81	NA	NA
		6	Soil	<1	45	NA	NA
Area 16	C-5	2	Soil	<1	<30	NA	NA
		4	Soil	<1	<30†	NA	NA
		6	Soil	<1	<30†	NA	NA
	C-6	2	Soil	10	350†	120	120
		4	Soil	<1	400	230	230
Area 21	C-1	6	Soil	<1	<30	NA	NA
		2	Soil	<1	180	<30	<30
		4	Soil	<1	230	<30	<30
	C-2	6	Fuel	<1*	550	91	91
		2	Fuel	<1	110	<30	<30
		4	Soil	10	68†	<30	<30
		6	Soil	10	37	NA	NA

NA = Not analyzed.

NA** = Not analyzed, sample lost.

* Late eluting peaks detected.

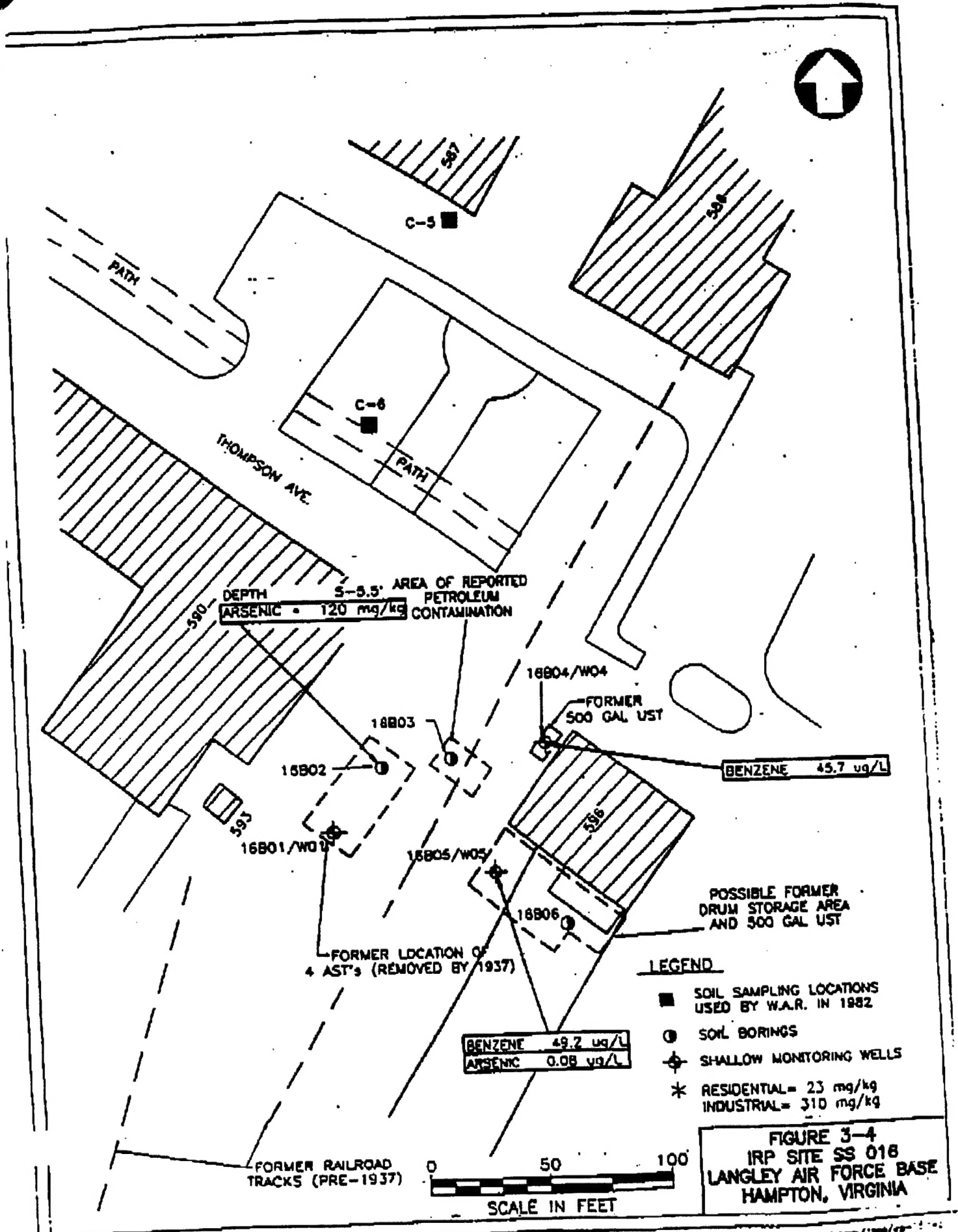
† Sample previously purged.

Source: WAR, 1982.

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Langley Environmental

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Source: Radian and Law, 1995.

Table 3-2

Analytical Results for IRP Site SS-16

Compound	Value ppm	Location/Depth	MCL ppm	RBC ppm
Soil	mg/kg			
Arsenic	120	16B02/5'-5.5'		23/36 ³
Groundwater	mg/L			
Arsenic	.00008	16W05	0.05	
Benzene	.0492	16W05	0.005	
Benzene	.0457	16W04	0.005	

¹National Primary MCLs from 40 CFR Section 141.61 for organics and Section 141.62 for Inorganics (effective 30 July 1992).

²USEPA, Region III, Risk Based Concentration Table, Second Quarter 1994.

³Residential Soil RBC

⁴Arsenic (as carcinogen)

TABLE 3-1
STORAGE TANKS AT UST SITES
Langley AFB, Hampton, VA

SITE	QTY	TANK SIZE (Gallon)	CONTENTS	STATUS
SS-16	4	(a)(b)	Unknown	Removed
	2	550	Fuel Oil	Removed
SS-24	1	6,000	Waste Oil(c)	Abandoned in Place
	1	8,000	Waste Oil(c)	Abandoned in Place
ST-48	8	6,000	Gasoline/Diesel	Abandoned in Place
	1	1,000	Fuel Oil	Abandoned in Place
	1	550	Waste Oil	Abandoned in Place
OT-49	2	10,000	Fuel Oil	Abandoned in Place
ST-50	2	550	Fuel Oil	Abandoned in Place
SS-52	1	550	Gasoline	Replaced

(a) Size unknown

(b) Aboveground storage tank(s)

(c) Includes an unknown quantity of mixed solvents and hydraulic fluid